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THE "PHOTOFLUX" SERIES OF FLASHBULBS

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It is known that right in the beginning of photography, about 100 years ago, photographs were already being taken with a flash of light. This is probably even the oldest form of artificial-light photography, since with the means of permanent artificial light available in those days and the very poor sensitivity of the sensitive plates of that time, the exposures would certainly have been unduly long. The flash was obtained by burning i.a. magnesium powder.

Nowadays flashlight technique has reached a very high degree of refinement, as will be shown in this article.

Introduction

It was about 20 years ago that the "Photoflux" and similar flashbulbs were introduced to replace the old flashlight produced by combustion of a mixture of magnesium powder and an oxidizer in air. Their success was remarkable. Only in one application, for "magnesium flash bombs " when photographing from aircraft, is the "open" flashlight still in use, but otherwise it was very soon ousted by the "closed" flashlight. "Ousted" is not really the right word, since with their safe, clean and perfectly controlled working the modern flashbulbs have not only replaced the open flashlight but by their introduction have brought about a vast expansion in the field of flash photography. The flashbulb has become the inseparable companion of the press photographer — probably the foremost user of this article — and also in amateur photography it has taken a very important place. Many are the accessories that have in consequence been brought on the market for flash photography, such as reflectors and synchronizers, and many are the types of cameras that have been fitted with built-in synchronizers with contacts for one or more flashbulbs. In this connection mention may be made of the Philips flash camera, which has not only a synchronizer but also a lamp socket and reflector built into it [1]).

The principle of the "Photoflux" lamp was dealt with in this journal as far back as 1936 [2]). The principle has not been altered much, nor is there much difference in the appearance of the present-day lamp compared with that described at the time. The properties of the lamp however have been improved or changed in a great many respects, so that it is deemed opportune to discuss these "Photoflux" lamps anew; they are now being produced in a series of five types, some of them in different colours. We shall not particularly dwell upon the points of resemblance and difference compared with the older types, since this is not likely to be of much interest to the reader.

General construction of "Photoflux" flashbulbs

The flash from the "Photoflux" flashbulbs is brought about by the combustion of fine wire of an aluminium-magnesium alloy (with 5-7% Mg). A certain quantity of this wire — it is only 32 μ thick — is placed loosely in a bulb like that of an incandescent lamp, and during this process it is given a sort of "permanent wave", so that it is uniformly distributed all over the inside of the bulb in the form of a loosely knit, resilient ball. The sealed bulb is further filled with oxygen under somewhat less than atmospheric pressure and contains also an ignition filament which can be heated by an electric

1) See Philips Techn. Rev. 12, 149, 1950 (No. 5).

2) J. A. M. van Liempt and J. A. de Vriend, The "Photoflux", a light-source for flashlight photography, Philips Techn. Rev. 1, 289-294, 1936.

current from an external source (see *fig. 1*). When the filament reaches a certain temperature an explosive paste applied to it ignites and the glowing particles scattered from it in turn ignite the ball of aluminium-magnesium wire at numerous points simultaneously, so that the whole ball burns away in a very short time.

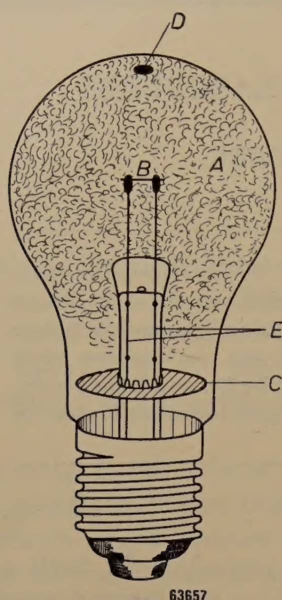


Fig. 1. Construction of a "Photoflux" flashbulb. *A* a ball of curled aluminium-magnesium wire, *B* ignition filament with explosive paste, *C* aluminium plate, *D* spot of cobal salt, *E* fuse wires.

The electric current for the ignition is usually derived from a battery, but the large types of "Photoflux" lamps can also be ignited from the lighting mains, for which purpose these types are provided with a quick-acting fuse fitted in the lamp base and forming the connection to the mains lead; owing to the arcing in the gas following upon the ignition of the lamp a very heavy current is drawn from the mains, but then this safety fuse burns through so quickly as to save the fuse of the house mains.

The burning of the Al-Mg wire causes the oxygen in the lamp to be heated quickly to a high temperature, so that for a moment — until the gas has cooled down again — the bulb comes under a pressure that may amount to several atmospheres. A normal cold bulb can withstand this pressure, but in the flashbulb the wall of the bulb is also subjected to a bombardment of glowing particles of ash which are apt to crack the glass where they strike against it, and in that weakened condition the bulb cannot withstand the pressure. The bulbs of the "Photoflux" lamps are therefore lined with a layer of lacquer in which the glowing particles are cooled down before they are able to damage the glass. Near the base of the lamp, where the layer of lacquer cannot be applied owing to the sealing of the bulb, the glass is protected against the glowing particles by an aluminium plate mounted in the neck of the lamp (see fig. 1).

External damage, such as scratches, which may easily result when, for instance, a couple of unpacked flashbulbs are carried in the coat pocket and rub against each other, may likewise so weaken the bulbs that they are unable to withstand the pressure set up inside them when they are ignited. A coating of lacquer is therefore also applied to the outside of the bulb to prevent scratching of the glass. At the same time this outer coating serves to keep the fragments together and thus render the explosion harmless in the event of the bulb bursting in spite of these precautions. For that reason the coating is made fairly thick and with a tough kind of lacquer, while it is also coloured light yellow so that it can easily be checked; this colouring has hardly any effect upon the radiation of the light.

The effectiveness of these two layers of lacquer in preventing the bulbs from bursting is evident from the random tests taken as a regular check in the manufacture of these lamps. Of the tens of thousands of lamps ignited for these tests in the course of the last few years less than one in a thousand have exploded.

This applies to lamps where the bulbs were quite intact prior to ignition. Bulbs already showing slight defects, from whatever cause, are more likely to explode upon ignition, especially so when there are small cracks in the glass through which air can penetrate. To avoid this increased risk with such lamps, a spot of cobalt salt is applied on the inside at the top of the bulb of all "Photoflux" lamps; in pure oxygen this spot is blue, but when there is the slightest trace of water vapour (and this is always present in the air) it changes to pink, thus immediately betraying the presence of air in the bulb, in which case it is not advisable to use the lamp [3]).

"Photoflux" lamps that have served their purpose sometimes show a more or less extensive blackening of the laquer lining, while in some cases a bulge is to be seen in the outer coating of lacquer. These two phenomena might give rise to some doubt as to whether the layers of lacquer are after all the right solution of the explosion problem, since, if the

[3]) In addition to the slightly greater risk of bursting, when the lamps have sucked in air there is also the risk of faulty synchronization, owing to their light-time characteristic undergoing a change; cf. the final section of this article.

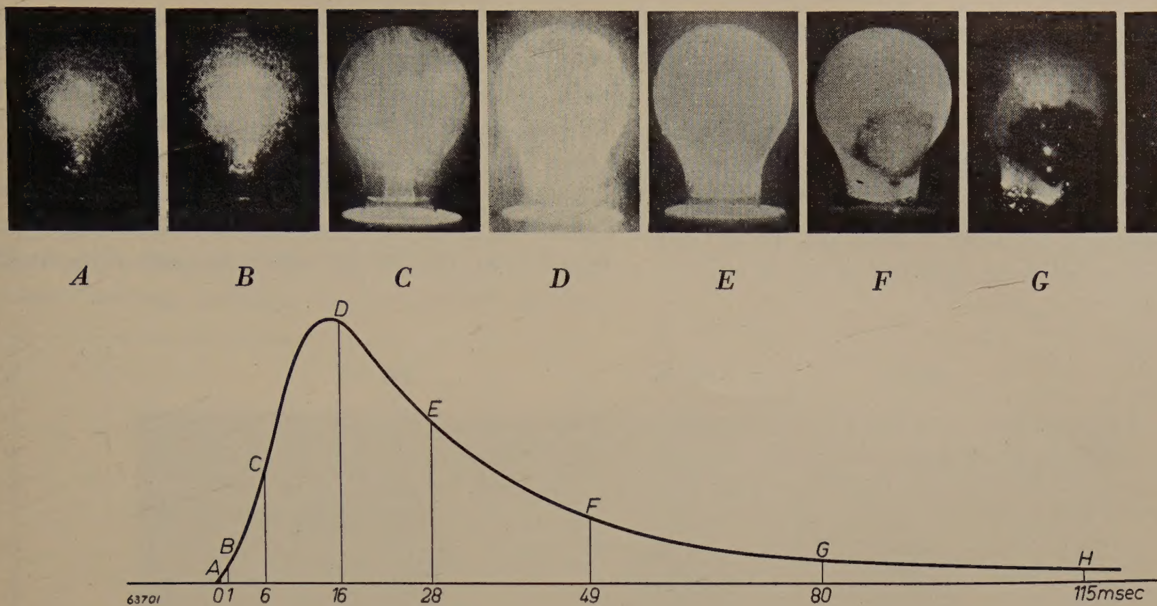


Fig. 2. Film of a burning "Photoflux" flashbulb taken at a speed of 3000 pictures per second. A number of cuts have been taken from the film corresponding to the moments indicated in the drawing (light-time characteristic) after the first picture reproduced (*A*). The film shows the formation of a black patch in the inner coating of lacquer.

blackening takes place at the beginning of the generation of the light, this will absorb some of the light, whilst as regards the bulge in the outer layer, if this is formed at the moment of maximum pressure from within, it will make the hope of sufficient support for a bursting bulb illusory.

Photographs taken with a high-speed camera (3000 pictures per second) of a series of "Photoflux" lamps in the course of being ignited have shown that there are no grounds for doubting the adequacy of the lacquer coatings. Both the blackening of the inner layer and the bulging of the outer coating take place after the main combustion and after the transmission of the light (*figs 2* and *3*). As a matter of fact, measurements of light output do not show any perceptible difference either between lamps with and lamps without an inner coating of lacquer.

The various types of "Photoflux" lamps

Fig. 4 shows the five types of "Photoflux" lamps that are now being made, the PF 110, PF 56, PF 45, PF 25 and PF 14. The numbers of this series roughly indicate the light output of the lamp in thousands of lumen-seconds (so-called photographic

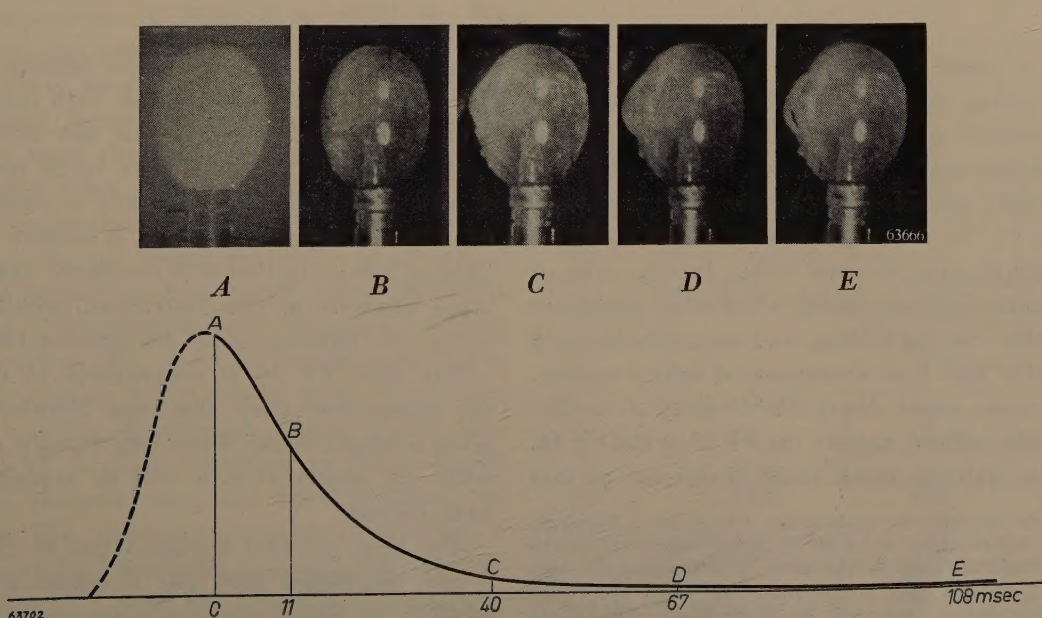
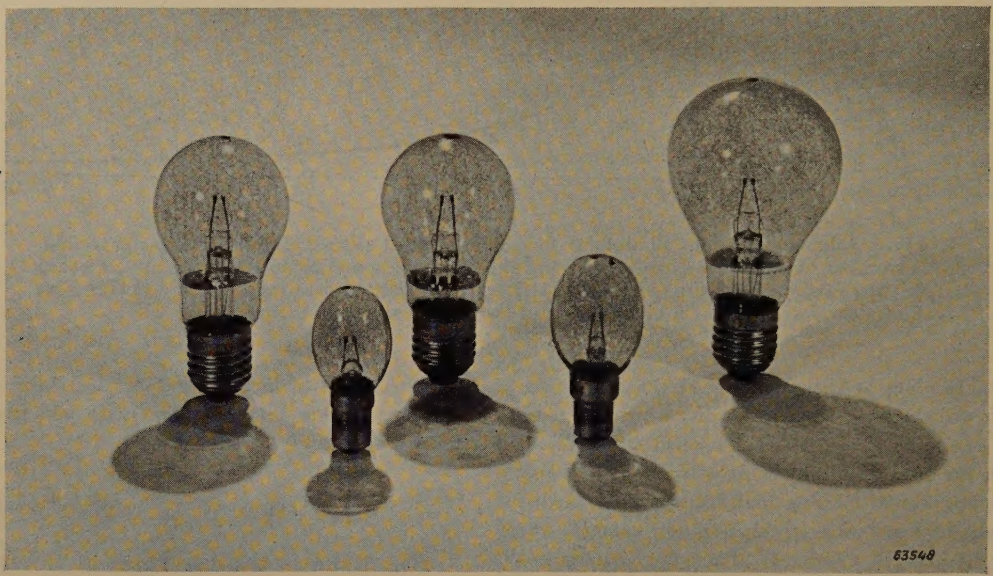


Fig. 3. Pictures taken from a film similar to that in fig. 2. This film shows the formation of a bulge in the outer coating of lacquer.

lumen-seconds, as explained below); thus the PF 56 yields 56,000 lumen-seconds [4]). To illustrate how enormous this quantity of light is, it might be mentioned that with the PF 56 lamp in a normal reflector at a distance of 4 m from the object, using a normal film and an exposure of 1/100th second, the diaphragm of the camera has to be closed down to $f/22$ to avoid over-exposure of the film.

PF 45 PF 56 PF 110



PF 14 PF 25

Fig. 4. The five types of "Photoflux" lamps. The PF 110 is used only in very special cases, the normal types for the professional photographer being the PF 56 and the PF 25, while the PF 14 is mainly for the amateur photographer. The PF 45 has a longer flash than that of the other types (see the last section of this article).

Such a small aperture is often undesirable, because owing to the great focusing depth also the background is brought out unpleasantly sharp. When photographing in a normal room, where it is not usually possible to get greater distances than 4 m, the PF 56 — and, a fortiori, the PF 110 — will therefore only be used when, for the sake of more artistic lighting (using a diffusing screen or illumination via the ceiling, and naturally losing a great deal of light), an abundance of light is needed. For the more usual direct illumination a smaller type mostly suffices, namely the PF 25 or the PF 14. For direct lighting these small lamps are in fact not so very much less effective as one might suppose from the difference in the number of lumen-seconds: since the lower-powered lamps are also smaller in dimensions, with a reflector of a certain size their light is more concentrated.

The PF 25 and the PF 14 are so small that a number of them can easily be carried in a pocket. That is why the PF 25, which in spite of its small dimensions still yields a good amount of light, has become particularly popular with press photographers. These small lamps are not fitted with a safety fuse and therefore have to be ignited with a 3-12 volt battery; they have a small bayonet type base and thus will not fit in sockets for normal lighting lamps, so that it is not likely that anyone, being unaware of this restriction, would ever try to use the lighting mains for igniting these lamps.

The type PF 45 is comparable to the PF 56 (in appearance they are even identical), but it gives a longer flash. What this exactly means and what the object of it is will be explained in the next section.

The light emitted by the types of "Photoflux" lamps mentioned here has a colour temperature of 4050 °K, which means that its spectral distribution resembles in the main that of the radiation from a black body having a temperature of 4050 °K.

[4]) It is the intention to replace the PF 56 by a flashbulb with a light output some 40 % higher than that of the PF 56 and to add to the series a new flashbulb with about 25 % less light output than the PF 56. The PF 45 will then also be replaced by a flashbulb with about 40 % higher light output. The new type number will then no longer correspond to the light output of the flashbulb.

However, the spectrum of the "Photoflux" lamps has a number of extra bands in the green; see *fig.* 5 [5]).

For normal black-and-white photographs a good colour rendering is obtained with this light. For colour photography, however, the spectral distribution of the light has to be different from this: daylight colour films have a spectral sensitivity that gives the right rendering of all colours only when "average daylight" is used, which means to

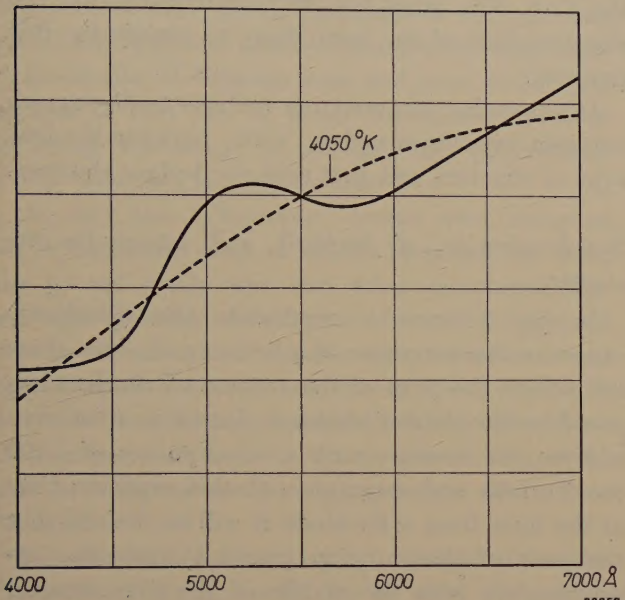


Fig. 5. Spectral distribution of the light emitted by a "Photoflux" lamp. The dotted curve represents the spectral distribution of the radiation from a black body of 4050 °K.

say that the light source has to have a colour temperature of about 5500 °K; the less commonly used artificial-light colour films are made for a colour temperature of 3200 °K or 3400 °K. For taking flash photographs on colour films some types of "Photoflux" lamps are therefore made also in two modified forms, one with a coating of blue lacquer to raise the colour temperature to about 5500 °K, the other with a yellow coating to give a colour temperature of about 3300 °K. For the blue lamps it was found necessary to choose a coating of lacquer such as would ensure sufficient absorption of the green to render the green emission bands harmless. The spectral transmission curve of the blue coating is represented in *fig. 6*, together with the spectral distribution curves of the blue lamp and of daylight, showing to what degree the colour temperatures have been matched. Of course, in the colour-temperature correction a certain loss of light has to be accepted, this amounting to about 50% with the blue lamps and about 10% with the yellow ones.

[5]) F. G. Brockman, J. Opt. Soc. Amer. 37, 652-659, 1947.

Some explanation has to be given of the figures quoted above for the total emission of light from the "Photoflux" flashbulbs as expressed in their type numbers.

When a luminous flux (or, perhaps better, a radiation flux) is measured in lumens this means that the radiation of each wavelength is given a value according to the sensitivity of the eye for that particular wavelength. For our purpose this is obviously not the right way. To give an example: the ultra-violet part of the radiation spectrum of any source of light (a rather large proportion of which passes through photographic objectives) is not included at all in the number of lumens determined in this way, because the eye is not sensitive to the ultra-violet, and yet the ultra-violet causes a considerable blackening of normal photographic material.

Furthermore, the measuring of the total radiation of the flashbulb — already in itself no simple matter — becomes rather precarious when we try to make the spectral sensitivity of the measuring instrument equal to that of the eye with sufficient accuracy. Such is evident, for instance, from the fact that when some years back the standard apparatus employed in the U.S.A. for the measurements was corrected all the numbers of lumen-seconds quoted for American flashbulbs had to be reduced by no less than 20%.

For these reasons, contrary to American usage, it is more logical give the amounts of light emitted by the "Photoflux" lamps not in visual but in photographic lumen-seconds. This unit is directly related to the desired effect of the lamp, thus not to the brightness as perceived by the eye but to the blackening of a photographic emulsion. The definition reads: A source of light yields one photographic lumen-second when, under the conditions of the D.I.N. standard specifications, it produces on an average orthochromatic emulsion the same blackening as that produced by one visual lumen-second from a sensitometer standard lamp. Measuring is now much less difficult, since instead of being obliged to imitate a very specific sensitivity curve (that of the average eye) it has been possible to fix as a standard an easily produced sensitivity curve closely approximating the said average emulsion.

The photographic lumen-second according to this definition (and the photographic lumen that is to be defined in like

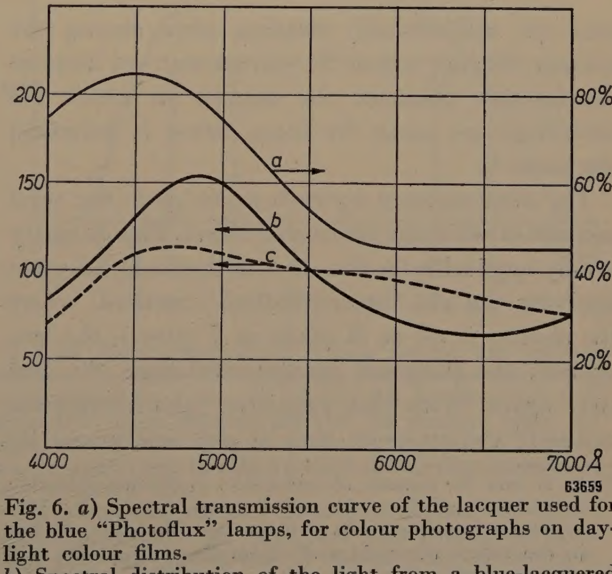


Fig. 6. *a*) Spectral transmission curve of the lacquer used for the blue "Photoflux" lamps, for colour photographs on daylight colour films.
b) Spectral distribution of the light from a blue-lacquered "Photoflux" lamp.
c) Spectral distribution of daylight (colour temperature about 5500 °K).

manner) is, it is true, related to the now more or less obsolete orthochromatic emulsion, but the numbers found prove to apply also for panchromatic emulsions to a fairly good approximation. For the "Photoflux" lamps, it is to be added, a photographic lumen-second is approximately equal to 0.7 visual lumen-second [6]).

The light-time characteristic of "Photoflux" lamps

Fig. 7 gives the average light-time curves of all "Photoflux" lamps excepting the PF 45. These curves have been produced by plotting the luminous flux (in photographic lumens) as a function of the

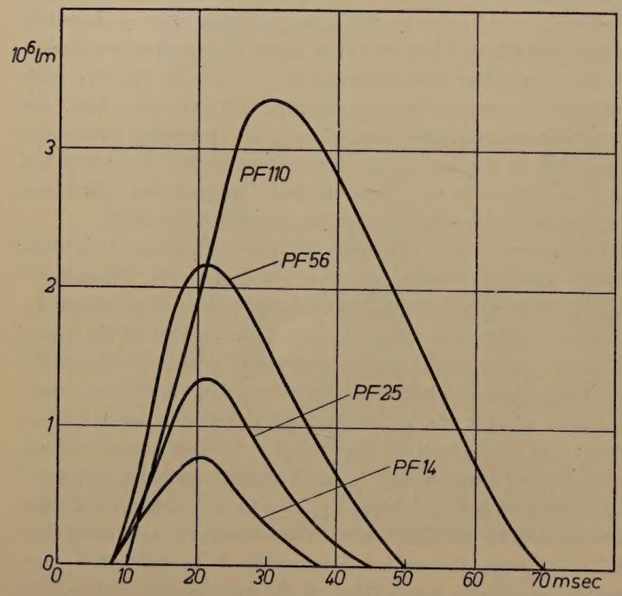


Fig. 7. Average light-time characteristics of the "Photoflux" lamps PF 110, PF 56, PF 25 and PF 14. The luminous flux (in photographic lumens) has been plotted as a function of the time (in msec) elapsing after switching on the current for the ignition filament.

time (in milliseconds) elapsing after closing the contact through which the electric current flows to the ignition filament; the manner in which the recordings are taken for these curves is described elsewhere [7]).

The area enclosed by each curve gives the total amount of radiation mentioned above. This quantity is only applicable for the effect of the flashbulb when applying the old "open-and-flash" method, where the shutter is set to *B* (ball) or *T* (time), the lens opened, the flashbulb ignited and then the lens shut again. With this primitive "synchronization method" the exposure time is not determined by the rather long time that the shutter is opened but by the duration of the flash. In the case of the PF 56, for instance, the exposure time is then about 1/40th second (disregarding the rather ineffective trailing edge of the curve in fig. 7). What constitutes an important advantage of the modern flashbulbs, however, is that they allow of a refined synchronization method whereby it is possible to photograph with much shorter exposures than the duration of the flash. Now what are the requirements that the characteristic of the lamp have to satisfy for this purpose?

In answering this question we have to distinguish between synchronization with between-the-lens type of shutters and that with focal-plane shutters.

Synchronization of flashbulb and between-the-lens shutter

In *fig. 8* curve *a* represents the (idealized) exposure characteristic of a between-the-lens shutter, where the part of the surface of the lens exposed by the shutter blades is plotted as a function of time, for instance with a set exposure of 1/100 sec. To take a photograph with this exposure time at the light from a flashbulb it will be desired that the peak of the emission (curve *b*) coincides approximately with the middle of the time interval during which the shutter is wide open. This is achieved by arranging for the shutter to be operated via the synchronizer, which first closes an electrical contact for the ignition of the flashbulb and then opens the shutter after a certain interval of time (T_0 in fig. 8).

In this case it is not the total number of lumen-seconds of the flash that is decisive for the blackening of the film but, approximately, the maximum

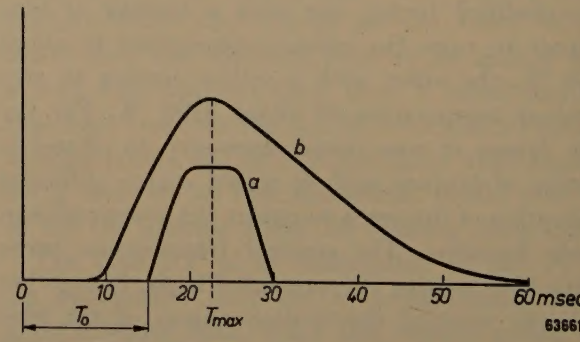


Fig. 8. *a*) Exposure characteristic of a between-the-lens shutter adjusted for an exposure of 1/100 sec. The part of the lens surface exposed by the shutter blades has been plotted as a function of time.
b) Light-time characteristic of the PF 56. The "maximum time" T_{max} is about 22 msec, like that of the PF 25 and the PF 14. The delay time T_0, i.e. the time which elapses between the closing of the contact for igniting the flashbulb and the releasing of the shutter by the synchronizer, has to be matched to the value of T_{max}.

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[6]) It is only for reasons of uniformity in the denomination that the visual lumen-second is used as a unit. This argument is nevertheless likely to turn the scale, so that in the future the ratings of "Photoflux" flashbulbs will also be expressed in this unit.

[7]) See, e.g., J. A. M. van Liempt and J. A. de Vriend, Physica, The Hague 4, 354, 1937; T. H. Projector and L. E. Barbrow, Rev. Sci. Instr. **16**, 51, 1945.

luminous flux (the number of lumens in the peak of the characteristic — with the PF 56 for instance more than 2 million).

The delay time T_0 of the synchronizer has to be matched, as fig. 8 shows, to the time taken for the flashbulb to develop its maximum amount of light after the ignition contact is closed; this is called the maximum time [8]). This time should therefore be equal, within a very narrow tolerance, to one fixed value for all flashbulbs of one type, and preferably it should also be equal for different types of flashbulbs of different sizes and even of different makes, so that any of them can be used without it being necessary to change the (adjustable) delay time of the synchronizer.

At first the "Photoflux" lamps were designed for a maximum time of about 30 msec, but after the second world war and when communication was again possible with the outside world it appeared that in the meantime American manufacturers had agreed upon a shorter maximum time, viz. 20-22 msec. In fact seveial cameras had been placed on the market with built-in synchronizers that could only be adjusted for a maximum time of at most 25 msec.

For the sake of uniformity, and so that the "Photoflux" lamps could also be used with those cameras, the maximum time of the PF 56, PF 25 and PF 14 lamps was then likewise reduced to approximately 22 msec. This change, which in the main amounted to a quicker ignition of the aluminium-magnesium wire, was effected by changing the composition of the explosive paste on the ignition filament. As a consequence of the more rapid ignition, however, also the force of the pressure to which the bulb is subjected was increased and thus there was a greater risk of the bulb bursting. This evil has been remedied, as the figures already quoted show, by reinforcing the outer coating of lacquer.

It is perhaps well to point out that there is only question of a "refined" synchronization as referred to here when it is desired (and possible) to cut off part of a relatively too long flash with a mechanical shutter. With the gas-discharge flashtubes which have begun to come to the fore in recent years [9]) the duration of the flash is only in the order of 10^{-4} sec, thus much shorter than the flash of the "Photoflux" lamps and also much shorter than the exposures that could be reached with any form of mechanical shutter. In the case of these lamps, therefore, it is always the duration of the flash that determines the exposure time, and any "synchronization" amounts only to an automatic application of the "open-and-flash" method.

Something similar applies for the so-called paste lamps, which are small flashbulbs not containing any aluminium-magnesium wire and having only an explosive paste which of itself produces a fair amount of light, while the duration of the flash is extremely short and accordingly also the maximum time is short (5 - 10 msec). Some cameras, namely the Kodak Six-20 and the Kodak-Brownie Reflex, are specially designed for use with these lamps, being fitted with a synchronizer having a fixed and very short delay time; ipso facto they cannot be used with "Photoflux" flashbulbs.

Synchronization of flashbulb and focal-plane shutter

In the case of a focal-plane shutter two "curtains" with a slit between them pass across the photographic plate or film. This permits of very short exposures, e.g. 1/1200 sec. The total time taken for the slit to travel from one edge of the plate to the other, however, is much longer than the exposure at each point of the plate; a normal is 30 msec, but in some, large, cameras it may even be more than 40 msec.

For all parts of the plate to be uniformly exposed when taking a flash photograph with a focal-plane shutter, the luminous flux of the flashbulb would have to be constant during the whole of the running time of the shutter. Since this is not possible of realization it has been stipulated as a practical requirement that the minimum and the maximum

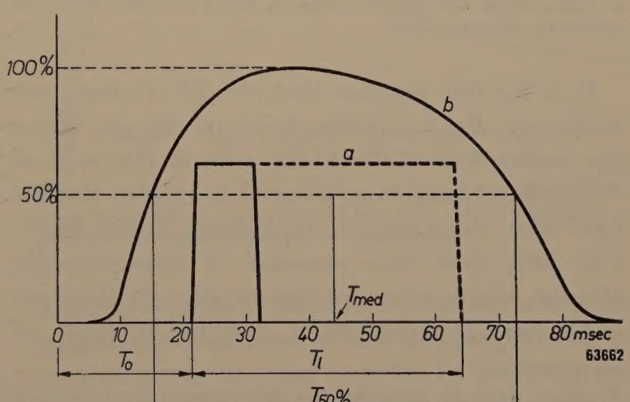

Fig. 9. *a*) Characteristic of a focal-plane shutter. The ordinate indicates the luminous flux passing through the slit. Owing to the movement of the slit however this luminous flux falls successively upon different parts of the sensitive plate: the exposure time of each part (indicated by the fully drawn lines for a point near the edge) is much shorter than the running time T_l of the slit.
b) Light-time characteristic of a flashbulb for use with a focal-plane shutter. The 50% flash time ($T_{50\%}$) has to be longer than the running time of the slit to avoid differences in exposure of the plate greater than a factor 2. The synchronizer has to start the shutter with a delay time $T_0 = T_{med} - \frac{1}{2}T_l$; T_{med} is the median time reckoned up to the middle of the 50% flash time.

8) The delay time should actually also be matched to the adjusted exposure time, but as this makes the matter very complicated one is usually satisfied if the ideal synchronization is obtained for only one exposure time. This must then be for the shortest exposure (say 1/500 sec), matching being the mos critical for this exposure.

9) See, e.g., S. L. de Bruin, An apparatus for stroboscopic observation, Philips Techn. Rev. 8, 25-32, 1946.

flux during that time shall in any case differ by no more than a factor of 2. From the light-time characteristic of a flashbulb it can be seen at once between what moments the lamp answers this requirement; these are in fact the moments at which the luminous flux has reached 50% of its maximum value, see *fig. 9*. The interval of time between these two points of the curve is called the "50% flash time". The time elapsing between the closing of the contact and the moment at which half of the 50% flash time has expired is denoted as the "median time".

For use with a focal-plane shutter one must therefore have a flashbulb with a 50% flash time at least equal to the running time of the shutter, while, independently of the exposure time, the synchronizer must have a delay time T_0 equal to the the median time less half the running time (cf fig. 9).

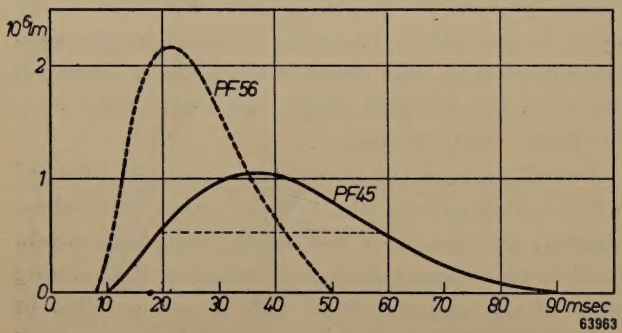

Fig. 10. Light-time characteristic of the "Photoflux" lamp PF 45, which has a 50% flash time of about 40 msec. (Note the differences of the scales of this figure and fig. 7!) For the sake of comparison the characteristic of the PF 56 has also been indicated (broken line).

It is for this purpose that the PF 45 has been developed. By a suitable choice of the gas filling the combustion of the Al-Mg wire in this type of "Photoflux" lamp is so delayed as to give the flat light-time characteristic reproduced in *fig. 10* [10]). The 50% flash time amounts to approximately 40 msec, which is long enough to allow of the lamp being used in combination with the majority of present focal-plane shutters, of small as well as large cameras.

It is of course also possible to use the PF 45 in combination with a between-the-lens shutter, but this cannot be said to be efficient. It has in fact only been possible to get the great width of the characteristic by accepting a relatively small maximum luminous flux, considering the very large total amount of light. With short exposures with an objective shutter a much greater effect is therefore obtained with the PF 56, which yields about the same total amount of light.

As already remarked, in appearance the PF 45 and the PF 56 are exactly alike, the difference only being seen from the type number stamped in the aluminium plate inside the neck of the bulb. To minimize the risk of mistakes being made, the type number of the PF 45 is marked in red letters.

To say that the PF 45 is not very efficient for short exposures with a between-the-lens shutter is only another way of giving expression to the fact that in the combination of a focal-plane shutter and a flashbulb the light that is available is rather inefficiently utilised. An improvement can only be made by shortening the running time of the slit. In the "Contax" camera, for instance, the running time has been reduced to about 15 msec by arranging for the slit to travel along the short side instead of the long side of the negative and, furthermore, by employing a stronger spring for driving the curtains. For this camera, therefore, the normal flashbulbs can be used, such as the PF 56 or the PF 25 (with 20 and 15 msec 50%-flash time respectively), with which for short exposures more economical use is made of the available light, owing to the high peak. On the other hand also the PF 45 can still be used, in which case another advantage of the short running time is to be derived, namely that, since only a part of the 50% flash time is used, the differences in luminous flux are much smaller than the permissible factor 2.

[10]) Other ways of changing the light-time characteristic in this sense are: eccentric ignition of the ball of wire, or the use of two kinds of wire (or a combination of wire and foil) in the bulb. In the latter case, owing to one of the components burning earlier and quicker, we get the sum of two characteristics with mutually displaced peaks, which, if the "saddle" between the peaks is not too deep, yields a characteristic similar to that given in fig. 10.

Summary. A description is given of the construction of the "Photoflux" flashbulbs. The light is produced by combustion of a ball of aluminium-magnesium wire in oxygen. An internal and an external coating of lacquer help the bulb to withstand the impact of the pressure resulting from the combustion. Up to now types of "Photoflux" lamps are being made, the PF 110, PF 56, PF 45, PF 25 and PF 14. The number behind the letters PF denotes the total amount of light in thousands of photographic lumen-seconds. The PF 56, PF 25 and PF 14 reach their maximum output of light about 22 msec after the electric circuit for the ignition is closed, so that they can be used in combination with practically any of the present synchronizers for between-the-lens shutters. The PF 45, which has a flatter light-time characteristic (the 50% flash time is about 40 msec), has been specially developed for use with cameras having focal-plane shutters.

AN INSTRUMENT FOR RECORDING THE FREQUENCY DRIFT OF AN OSCILLATOR

by W. W. BOELENS.

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A quartz oscillator has a frequency that is sufficiently constant for determining the frequency drift of an ordinary valve oscillator due to changes in temperature, for which purpose it is in fact the most suitable oscillator. This frequency drift, for instance that of an oscillator in a superheterodyne receiver, should be measured, however, in more than one position of the tuning capacitor. The problem is how to derive from one quartz crystal a number of reference frequencies spread more or less regularly over the frequency range of the oscillator to be measured. With the frequency-drift meter described here this problem has been solved by generating in a number of frequency-multiplying stages the twenty-fourth multiple of the crystal frequency and by an artifice deriving therefrom nine other multiples (the 19th up to and including the 28th).

It is a well-known phenomenon that after a valve oscillator has been switched on its frequency tends to drift. This is due to the fact that when an oscillator is switched on various sources of heat are brought into play (valves, resistors, transformers), so that the temperature and thus also the dimensions and hence the self-inductance or capacitance of the elements in the oscillating circuit undergo a gradual change. In practice it often takes some hours before a nearly stable condition is reached.

If the oscillator in question is part of a superheterodyne receiver and no adequate steps have been taken to counteract this phenomenon then, as a result of this frequency drift, the tuning of the apparatus may have to be readjusted several times to ensure satisfactory reception of a particular station. This is especially important in the reception of waves shorter than 10 m. Steps taken to prevent this may consist in the application of thermal insulators around the sensitive parts, the provision of ventilation, the use of circuit elements having a low temperature coefficient, etc.

Thus, after having applied one or more of these measures in an experimental apparatus, the designer of a receiving set is faced with the task of ascertaining whether the defect in question has been sufficiently remedied. This he does by measuring, with reference to a reference frequency, the frequency drift Δf_0 as a function of the time t after switching on, and this involves a series of measurements that may have to be extended over a number of hours. As a rule the first result will not be satisfactory; a suspected element may have to be replaced and the measurements then repeated all over again.

It does not suffice simply to measure the final value of the drift, because it may have previously reached much higher values. Thus the drift (and by that we mean here the absolute value of the frequency variation) as a function of time may show a maximum somewhere on the curve (*fig. 1*). This is due to the fact that the oscillating circuit comprises a number of elements (inductance of the coil and of the wiring, capacitance of the tuning capacitor, of the wiring and of the valve) some of

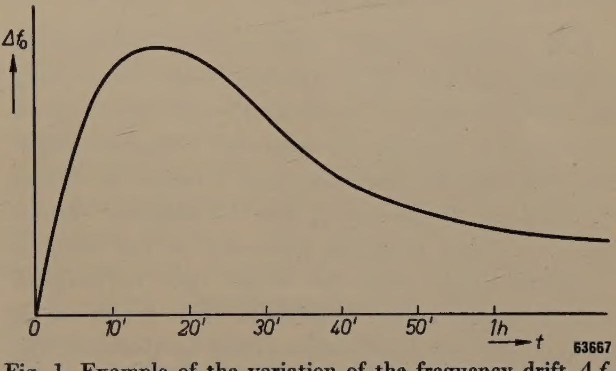

Fig. 1. Example of the variation of the frequency drift Δf_0 of an oscillator as a function of the time t after switching on. In the case drawn there is a maximum.

which may show a positive and others a negative temperature coefficient of the inductance or of the capacitance as the case may be. In course of time there may be a certain degree of compensation which does not exist at the beginning. It cannot be predicted at what stage the maximum may occur after switching on because of the great differences in the rate at which the various components reach their final temperature: the valves and those parts soldered onto the valve sockets may attain their final temperature in 10 or 15 minutes, whereas the parts mounted on the chassis may take a much longer time.

Consequently it is necessary to take the measure-

ments at sufficiently short intervals of time to ensure that any maximum occurring in the frequency drift does not escape notice. First they should be taken, for instance, every thirty seconds, then every minute, after a quarter of an hour every five minutes and after an hour every fifteen minutes. These intervals are not long enough to permit the observer to occupy himself seriously with any other work in between, so that for that reason alone such drift measurements cost a great deal of time.

Furthermore, the plotting of one drift curve alone does not suffice, it being necessary to plot a curve for several positions of the tuning capacitor, since the various capacitances in the oscillating circuit vary according to different functions of time, so that measurements have to be taken for different ratios of the component capacitances.

Very much time can therefore be saved by employing a recording instrument which, once it is started, automatically plots the drift cuive. Below a description will be given of such a recording drift meter in a form specially designed for testing F.M. radio receivers, the effective frequency range of which extends from 88 to 108 Mc/s.

Principle of the drift meter

F.M. receivers usually work with an intermediate frequency of 10.7 Mc/s, though lower values may also occur. It depends upon local conditions (near-by transmitters working on adjacent frequency channels) whether the designer finds it better to choose an oscillator frequency f_o for the receiver that is higher or lower than the frequency of the stations to be received, with the result that in practice both solutions occur. Therefore, in order to be of use for as many types of receivers as possible, the drift meter must be designed so as to cover a range extending from 88—10.7 = 77.3 Mc/s to 108 + 10.7 = 118.7 Mc/s.

The maximum drift that can be tolerated in this frequency range varies from 25 to 50 kc/s, according to the quality of the receiver, and thus the drift does not amount to more than about 0.05%, which is far too small to be measured directly with sufficient accuracy. The beat frequency of f_o is therefore formed with a neighbouring reference frequency f_r; this beat frequency shows a relatively much larger and thus more easily measurable drift.

The reference frequency f_r cannot be taken from a valve oscillator with an ordinary oscillating circuit because f_r would then itself show variations of the same order as the drift of f_o. For generating the reference frequency f_r one must therefore use a crystal-controlled oscillator. The difficulty that a crystal gives only one fixed value of f_r, whereas f_o is to be measured for a number of values (in the range from 77.3 to 118.7 Mc/s), can be met by choosing a crystal frequency f_c much lower than f_o, say $f_c \approx 4$ Mc/s, and producing, by n-fold frequency multiplication, a sufficient number of multiples of f_c which lie within this range and thus can serve as reference frequencies f_r. With $f_c = 4.232$ Mc/s (the value actually used) ten useful reference frequencies are obtained: $f_r \approx 80.4$, 84.6, 88.9 ... 118.5 Mc/s, a sufficient number of which will always lie in the range covered by the oscillator, no matter whether the oscillator frequency is higher or lower than the signal frequency, and for all intermediate frequencies up to well over 10 Mc/s. To get these ten reference frequencies it is necessary that n can assume the values 19, 20, 21 ... 28.

Now this is easier said than done. In the frequency range specified a 20-fold multiplication with such a selectivity that the adjacent multiples do not interfere cannot be brought about in one single multiplying stage [1]). It is true that good results could be reached by employing more than one stage, each with a small multiplication factor, but of course this only helps for those values of n which can be resolved into small factors, such as $24 = 4 \times 3 \times 2$, and $27 = 3 \times 3 \times 3$, so that the problem of getting n = 19, 22, 23, etc. cannot be solved in this way. To overcome this difficulty the following artifice has been employed.

As indicated in the block diagram of *fig. 2*, from the crystal frequency $f_c = 4.232$ Mc/s a 24 times as high reference frequency of 101.57 Mc/s is obtained in three stages. Both a voltage of this frequency $24 f_c$ and the normal voltage of the oscillator frequency f_o are applied to the mixing valve M_1 of the receiver under test. The voltage at the output of this valve has the much lower beat frequency $|24 f_c - f_o|$. After amplification, accompanied by the removal of undesired combination frequencies by means of a tuned circuit, this output voltage is applied to the input *1* of a second mixing valve M_2 forming part of the drift meter. To the input *2* of the latter valve a voltage is applied having the crystal frequency f_c itself and of such an amplitude and bias that the valve is rendered conductive

[1]) In principle the series of harmonics obtained without this selectivity are just suitable for the purpose, but the components are so small in amplitude that considerable amplification is necessary, and at frequencies of about 100 Mc/s this gives rise to great difficulties. It is furthermore unknown which of the harmonics is serving as a reference frequency.

only for a short time at the positive peaks of the voltage at the input *2*. This has the same effect as if this were a pulsatory voltage with the repetition frequency f_c. Consequently the valve shows a conversion conductance — the ratio of the A.C. output current with the beat frequency to the A.C. input voltage at *1* — which, as a function of the

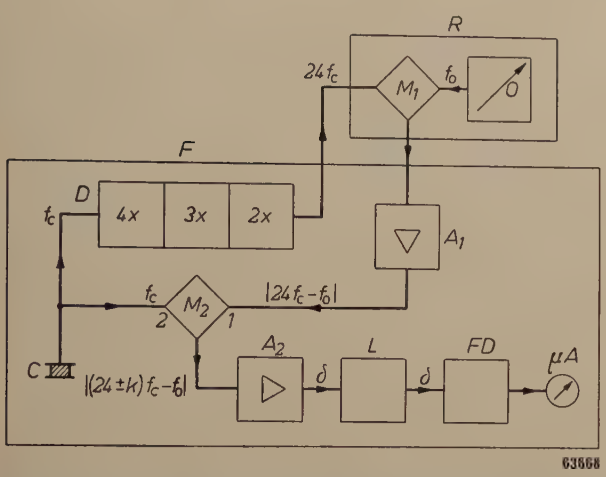

Fig. 2. Block diagram showing the principle of the drift meter. *R* receiver with oscillator *O* (frequency f_o) the drift curve of which is to be recorded, and mixing valve M_1. *C* quartz oscillator (frequency f_c), *D* frequency multipliers (24 ×), M_2 second mixing valve, A_1 and A_2 amplifiers, *L* limiter, *FD* frequency detector, μA recording moving-coil meter with scale calibrated in frequencies. The parts within the rectangle *F* belong to the drift meter.

frequency at input *1*, is approximately equal for frequencies f_c and not too large multiples of f_c. Thus, in the main, the output voltage of the valve contains not only components with the frequencies $|24\, f_c - f_o \pm f_c|$ but also components with $|24\, f_c - f_o \pm k\, f_c| = |(24 \pm k)\, f_c - f_o|$, where $k = 1, 2, 3$ and so on. The shape of the pulse is such that the components with $k = 1 \ldots 5$ are present with the required amplitude. The effect is therefore as if the reference frequencies $19 f_c \ldots 23 f_c$ and $25 f_c \ldots 28 f_c$ were all present simultaneously (the omitted term $24 f_c$ will be dealt with later; $29 f_c$ is not in the desired range and can be left out of consideration). After f_o has been brought sufficiently near one of the above reference frequencies by turning the tuning knob of the receiver, the small difference δ between these two can easily be separated with a low-pass filter from the much larger differences existing between f_o and the other multiples of f_c and which are about equal to f_c or several times f_c (thus 4 Mc/s or higher). If the frequency f_o of the oscillator under test changes by an amount Δf_o, then δ changes by the same amount, and this amount is usually considerable compared with δ. How this drift is detected and recorded will be shown below.

Let us now consider the case where f_o lies in the neighbourhood of $24 f_c$, and let the difference again be δ. This difference will then be present already at the output of the first mixing valve, so that in this particular case there is no need of the second mixing valve. Thus the second mixing valve could in this case be by-passed, but it has been found that the switches which would then be required can be dispensed with and the circuit left unchanged, because in spite of the valve being unblocked and blocked with the high frequency f_c it still transmits the low frequency δ with sufficient amplitude.

By means of the second mixing process described — the mixing of $|24\, f_c - f_o|$ with f_c — it has thus been found possible to transpose the drift to a much lower frequency range, with only one fixed multiplication factor (24) of the crystal frequency, for ten different frequencies.

Further, it is necessary to record the relatively low output frequency δ of the second mixing valve varying according to the amount of the drift. This can be done, for instance, by generating a direct current which is (approximately) proportional to the frequency δ and causing this current to flow through a recording meter.

To produce such a direct current we have made use of a known frequency detector circuit. This is preceded by an amplifier (A_2 in fig. 2) and a limiter. The amplifier is needed because the output voltage of the second mixing valve is too small for the frequency detector to function properly; moreover it contains the filters blocking the voltage components with undesired high frequencies. The limiter clips the peaks of the amplifier output, so that an almost square wave voltage of constant amplitude is produced. The latter is necessary because the output current of the frequency detector has to be independent of the amplitude of the output voltage from the second mixing valve.

From the fact that the meter records only the absolute value of the difference between one of the standard frequencies $n f_c$ and the oscillator frequency f_o it follows that the recorded curve (e.g. *fig. 3a*) leaves one in doubt as to whether f_o was smaller than $n f_c$ (fig. 3*b*) or greater (fig. 3*c*). This question can be solved by slightly turning the tuning knob of the receiver such as to make f_o somewhat larger and then noting in which direction the deflection of the meter is thereby changed; if the meter reading is reduced then f_o was smaller than $n f_c$; if it is increased f_o was greater.

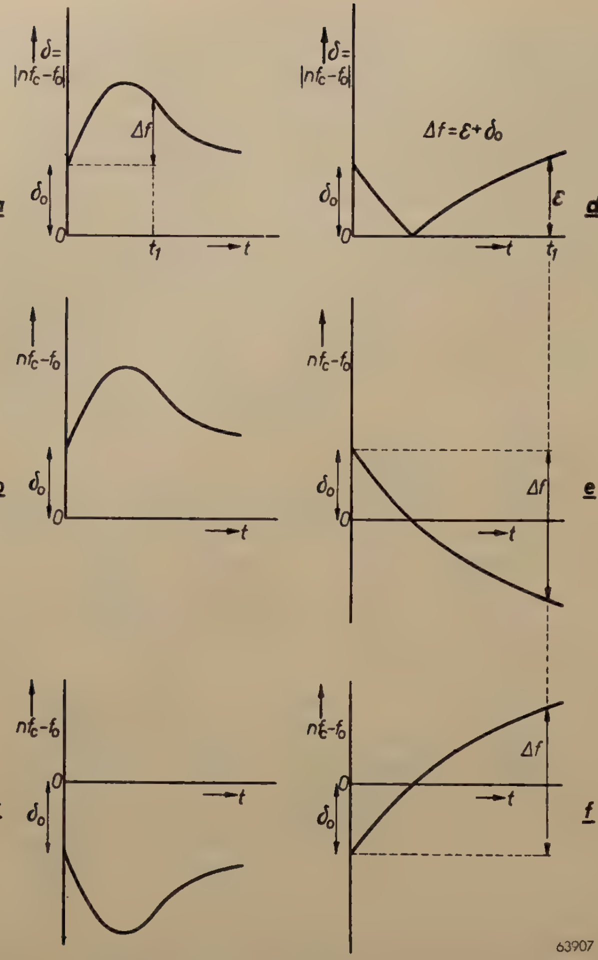

Fig. 3. *a*) Example of a recording. The frequency drift Δf at the moment $t = t_1$ is the reading at t_1 less the original deflection δ_0. The variation of $n f_c - f_o$ may have been according to (*b*) or (*c*); it is easily determined which of these two possibilities it was by purposely increasing f_o a little.
A turning point in the recording (*d*) is to be ascribed to $nf_c - f_o$ passing through zero according to (*e*) or according to (*f*). In (*d*) the drift at the moment $t = t_1$ is obtained by adding the initial value δ_0 to the deflection ε.

The recorded curve may also show a turning point on the zero line (fig. 3*d*), this being the case when the difference between $n f_c$ and f_o has passed through zero during the test. The trend of $nf_c - f_o$ may then have been according to fig. 3*e* or fig. 3*f*. By purposely increasing f_o a little it can be decided which of the two applies.

The manner in which the amplitude of the frequency drift has to be read from the recorded curve is indicated in figs 3*a* and 3*d*.

Form of execution

We shall now briefly discuss some details of the various component parts.

Crystal oscillator

Owing to use being made of a quartz crystal with a "temperature-independent" cut, the frequency f_c does not change by more than $1 : 10^6$ per °C temperature variation. This is so little that in our case it is not necessary to place the crystal in a thermostat, and this is fortunate in that it avoids the long waiting time involved in thermally balancing the thermostat. By providing ample ventilation openings in the casing containing the apparatus and also protecting the crystal with heat-insulating material, it has been possible to limit the final value of the frequency drift of the crystal to about 40 c/s and thus the drift of the standard frequency to about 1000 c/s, which is sufficiently small for our purpose.

The functioning of the crystal oscillator and the multiplying stages can be checked by measuring the grid current of the valves employed in these stages, for which purpose a micro-ammeter with switch is provided.

Amplifiers and mixing stage

In *fig. 4* a somewhat simplified diagram is given representing the circuit of the first amplifier (A_1 in fig. 2, with an EF 40 valve) and the second mixing valve M_2 (the hexode part of an ECH 41 valve). Between these two valves is a circuit, which can be tuned to the frequencies f_c, $2f_c$, $3f_c$ $4f_c$ and $5f_c$, according to whether the drift is to be measured at $f_o \approx 23f_c$ or $25f_c$, $22f_c$ or $26f_c$, ... $20f_c$ or $28f_c$, or $19f_c$ respectively. In these five cases the absolute bandwidth has to remain the same, this being achieved by switching only the inductance and leaving the capacitance and parallel resistances unchanged. The circuit is so arranged that the gain at a frequency deviating 0.2 Mc/s from the resonance frequency (the drift can be measured to 0.1 Mc/s maximum) is not more than 3 dB less than at resonance. For measuring at

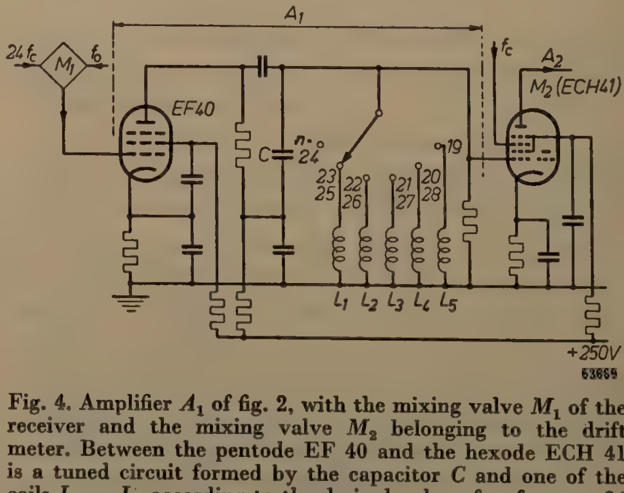

Fig. 4. Amplifier A_1 of fig. 2, with the mixing valve M_1 of the receiver and the mixing valve M_2 belonging to the drift meter. Between the pentode EF 40 and the hexode ECH 41 is a tuned circuit formed by the capacitor C and one of the coils L_1 ... L_5 according to the desired value of n; for $n = 24$ the inductance branch is interrupted.

$f_o \approx 24 f_c$ the inductance branch is interrupted, so that an ordinary resistance-capacitance coupling is left.

Limiter and frequency detector

The circuit of the limiter and of the frequency detector is represented in *fig. 5*.

The limiter works with two diodes (D_1, D_2). The cathode of D_1 is kept at a constant potential $E \approx +20$ V.

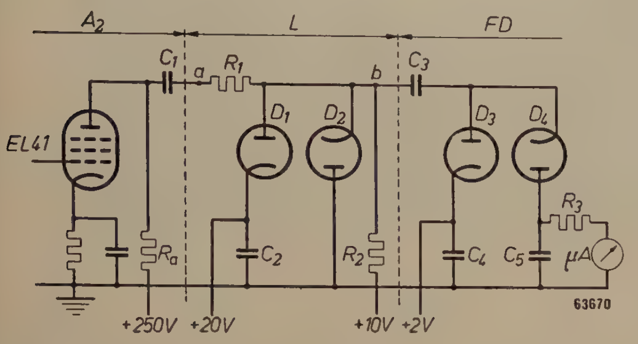

Fig. 5. Circuit diagram of the limiter (L) and of the frequency detector (FD). EL 41 output valve of the amplifier A_2 (fig. 2), with the anode resistor R_a. D_1 ... D_4 diodes EA 50. C_1, C_3 coupling capacitors, C_2, C_4, C_5 smoothing capacitors, μA micro-ammeter with resistor R_3. The function of the resistor R_2 is to keep the mean potential of the point b at + 10 V.

At the point a there is practically the same alternating voltage as at the anode of the output valve in the amplifier A_2; the amplitude of this alternating voltage is much greater than E. The diode D_1 passes current only when the alternating voltage at a is greater than E, and the diode D_2 conducts when the potential of a is negative. Disregarding voltage loss in the diodes, the potential of the point b is then $+E$ and zero respectively. The transition between these two values takes place in the very short intervals during which no current flows through either of the diodes.

Thus the limiter supplies an almost square-wave output voltage, with alternately the values $+E$ and zero. Since b is connected via the resistor R_2 to a point with the potential $\frac{1}{2}E$, the positive peaks of the alternating voltage at a are cut off as much as the negative peaks, so that the intervals during which the voltage at b assumes the values $+E$ and zero have the same length.

The frequency detector, which is of a known type [2]), similarly has two diodes (D_3, D_4). Connected in series with D_4 are a resistor R_3 and a micro-ammeter, these being shunted by a smoothing capacitor C_5. In order to avoid the possibility of the diodes causing a certain zero current to flow through the meter while no external voltage is applied, the cathode of D_3 is biased with a small positive potential $E_0 \approx 2$ V.

The formula for the current I flowing through the meter is:

$$I = \frac{\delta\, C_3}{1 + \delta\, C_3 R_3} (E - E_0)\,, \quad . \; . \quad (1)$$

where δ is the frequency of the pulsating voltage at the terminal b, C_3 the value of the capacitor connected in series with the diodes, while R_3 includes the resistance of the micro-ammeter.

The formula (1) can be derived in the following way, ignoring the voltage loss in the diodes.

When the voltage at the terminal b is zero, in the stationary state there is a voltage across C_3 equal to the voltage $V = IR_3$ across C_5. When the voltage at b suddenly changes from zero to $+E$ then C_3 receives via the diode D_3 a charge equal to $C_3\,(E - V - E_0)$. When the voltage at b drops again from $+E$ to zero this charge flows via the diode D_4 to R_3 and C_5 connected in parallel. This takes place δ times per second, so that the mean current I amounts to

$$I = \delta\, C_3\,(E - IR_3 - E_0).$$

Solving this equation for I leads to formula (1).

As can be seen from formula (1), the direct current I is practically proportional to the frequency δ if care is taken that $\delta\, C_3\, R_3 \ll 1$. This is what is in fact done in cases where the detection has to be as linear as possible. In our case, however, the meter need not record the frequency on a purely linear scale; in fact this is even undesirable, because with high values of δ, which occur while tuning f_o near to one of the reference frequencies, the meter would be overloaded. For this reason R_3 and C_3

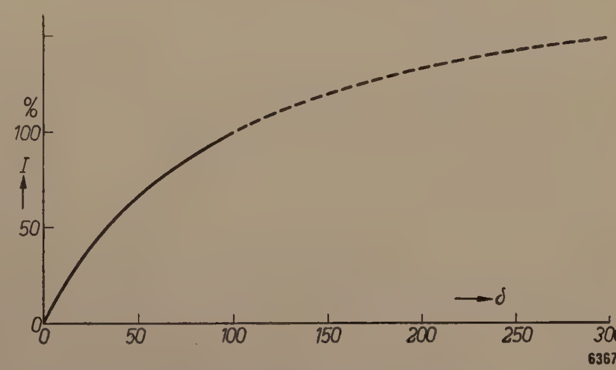

Fig. 6. The direct current I flowing through the micro-ammeter (in % of the current required for full deflection) as a function of the frequency δ in kc/s at the input of the frequency detector.

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[2]) S. W. Seeley, Ch. N. Kimball and A. A. Barco, Generation and detection of frequency-modulated waves, R.C.A. Review 6, 296-286, 1942; reprinted in Frequency Modulation, Vol. I, pp. 147 et seq. (R.C.A., Princeton, N. J., U.S.A.).

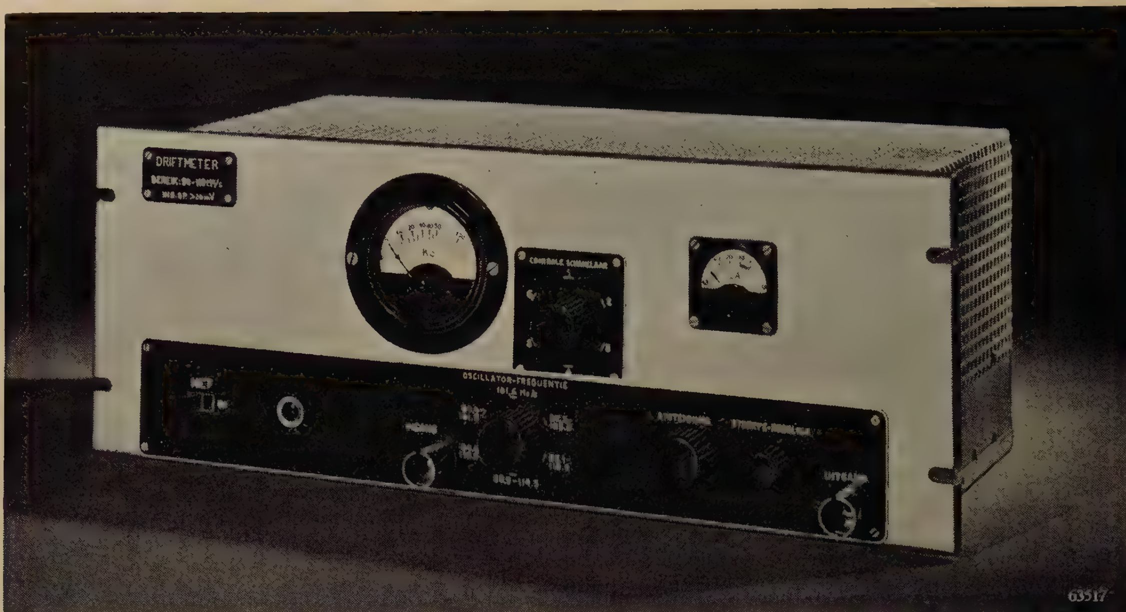

Fig. 7. Frequency-drift meter, in a form suitable for mounting in a rack. The left-hand meter, calibrated in kc/s, is used for preparatory adjustments; the recording meter is not shown in the illustration. The right-hand meter is used to check the various grid currents selected by the knob in between them. Underneath is the knob for selecting the desired reference frequency (n = 19 ... 28), cf. fig. 4.

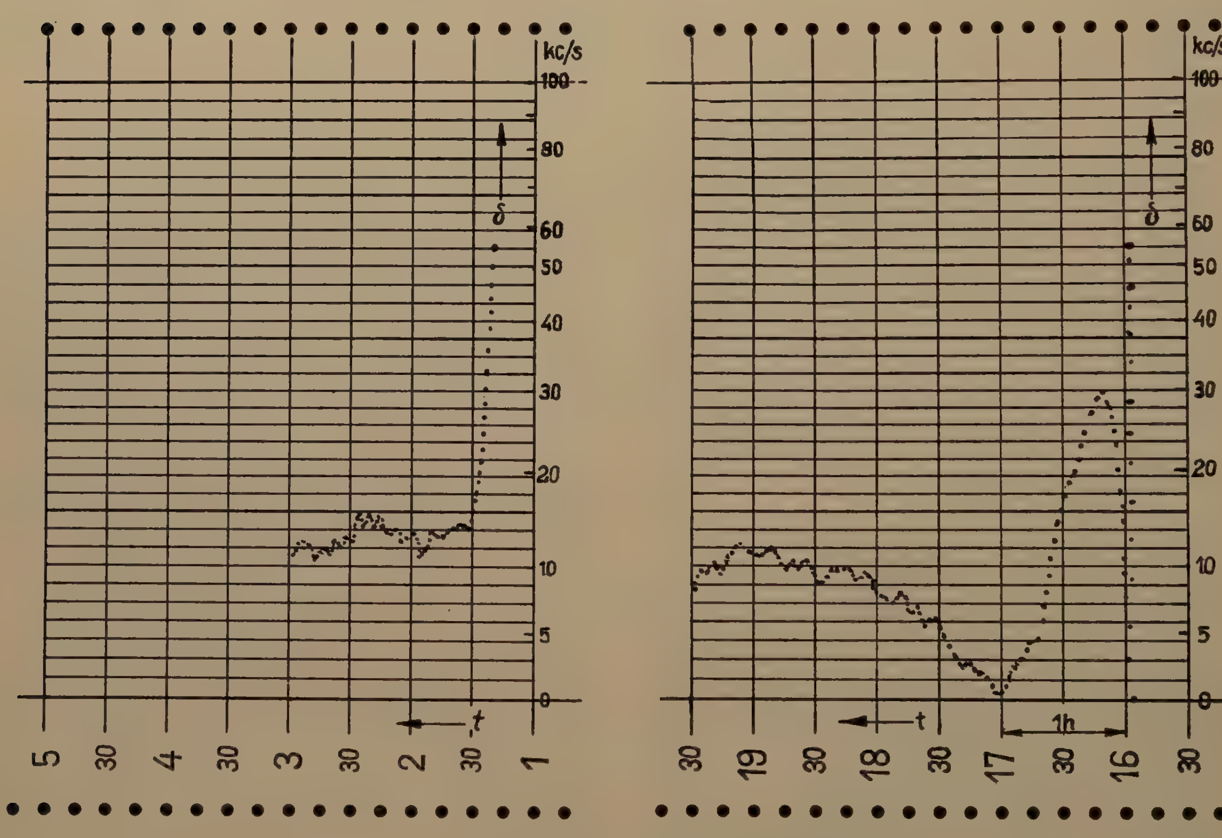

Fig. 8. Two recordings. The first shows a just acceptable drift of 55 — 12 = 43 kc/s. The second recording shows a turning point five minutes after the start, and at the end of 15 minutes a maximum at which the total drift is 55 + 30 = 85 kc/s. After a second turning point a second maximum is reached, at about three hours from the start; it shows a frequency drift of 30 + 10 = 40 kc/s with respect to the first maximum. If only the difference between the frequencies at the start and that at a moment three hours later had been measured the acceptable amount of 55—10=45 kc/s would have been found, but the quite unacceptable maximum drift of 85 kc/s would have remained unnoticed.

have been so chosen that with $\delta = 100$ kc/s the value of $\delta C_3R_3 = 1$. The curve $I = f(\delta)$ then assumes the shape represented in *fig. 6*. There thus is no longer any risk of overloading, while the frequency is still sufficiently legible over the whole range, especially so with small values of δ, so that even a small frequency drift can still be accurately determined.

In the form in which it is shown in *fig. 7* the drift meter has two micro-ammeters connected in series with the resistor R_3 (fig. 5): a normal built-in meter and a recording instrument (full deflection at 34 μA) kept separate. While the test is being started the readings are taken from the built-in meter. The frequency scale of the built-in meter runs up to 150 kc/s, and that of the recording meter to 100 kc/s.

Finally, in *fig. 8* two recordings are reproduced, one showing an acceptable drift and the other an intolerably large drift.

Summary. The frequency-drift meter described here has been designed for measuring the frequency variation of the oscillator in various types of superheterodyne F.M. receivers in the 88-108 Mc/s band. The drift meter is controlled by a quartz crystal with frequency $f_c = 4.232$ Mc/s, of which the 24-fold frequency (101.6 Mc/s) is obtained with the aid of multiplying stages. In the mixing valve of the receiver this harmonic is mixed in the usual way with the oscillator voltage having the frequency f_o that is to be observed, The output voltage, which contains, inter alia, the beat frequency $|24 f_c - f_o|$, is mixed with a voltage of the crystal frequency in a second mixing valve incorporated in the drift meter and so adjusted that it is rendered conductive only at the peaks of the latter voltage. The result is that from this second mixing process frequencies such as $|24 f_c - f_o \pm k f_c| = |(24 \pm k) f_c - f_o|$, with $k = 1, 2\ldots$ are obtained, so that, with only one multiplier working with good selectivity, a series of reference frequencies, $(24 \pm k) f_c$, are available which can be separated by means of a circuit tuned to one of the frequencies kf_c. In this way, in the drift meter described ten reference frequencies are available, from $19f_c = 80.4$ Mc/s up to and including $28f_c = 118.5$ Mc/s.

After amplification and limitation, the output voltage of the second mixing valve, with frequency $|(24 \pm k) f_c - f_o|$, produces at the output of a normal frequency detector a direct current which is approximately proportional to the frequency variation and thus also to the drift of f_o. This direct current is recorded as a function of time by a recording meter and thus a great deal of time in the regular checking of the drift of receivers is saved.

THE PERMISSIBLE BRIGHTNESS OF LAMP FITTINGS

by D. VERMEULEN and J. B. DE BOER. 628.95:628.972:535.241.44

The interest in the problems of "brightness engineering" is to a certain extent typical for changes that have taken place in the last decades in our conceptions about the working man. Whereas formerly interest was devoted mainly to the physiological conditions for the proper performance of a task, nowadays also the psychological factors that play a part are considered, and where formerly one spoke of efficiency now one speaks of "comfort".

Brightness engineering

With the development of the sources of light in the last 50 years it has become possible to reach high levels of indoor illumination in an economical manner. For the period up to about 1935-1940 the use that has been made of this possibility may be described as the adequate illumination of the working plane. It was realized that for numerous tasks to be performed properly, both in industry and in the home, reasonably high levels of illumination were needed, and from the experience gained in this field lighting standards were drawn up, in the form of tables giving the recommended illumination for all possible kinds of work [1]).

The principle underlying such standards is in all cases: it must be possible to see clearly and quickly what has to be seen when performing a task. However, as lighting equipment came to be installed more and moie in accordance with this principle it became evident that it is not sufficient to consider only the visibility of the object upon which one is working. While a task is being performed the eyes are not directed continuously upon the work in hand, there being always shorter or longer intervals during which one looks up from one's work into the surroundings in the normal way. These intervals should be a rest to the eyes, a brief relaxation from concentration upon the work: thus the lighting should give a feeling of comfort.

It is particularly with the high levels of illumination now often applied that this additional requirement assumes importance. The condition of "comfortable" lighting implies that the surfaces upon which the eye falls when looking up must not contrast too strongly in brightness with the work area. Consequently, on the one hand there must not be any very dark corners, while on the other hand the greatest brightness in the surroundings (i.e., in the case of direct lighting, the brightness of the lamp fittings) must not be so great that one becomes unpleasantly conscious of its presence, or at least there must not be so many fittings in the room that the eye cannot very well escape them when looking up. It is just with high levels of illumination however that very many and/or very bright fittings have to be used, so that there is a great chance of the lighting causing discomfort to the eye [2]).

Since this new point of view concerning the distribution of brightnesses in the surroundings has come to the fore, in the course of the last 10-15 years illumination engineering has entered a new phase, the phase of what has been named in America "brightness engineering".

There are, of course, other factors which help to decide whether people working in a room for a long time find the lighting comfortable or not. We have only to mention the colours, shadows, possible glitter and the aesthetic appearance of the room. Here we shall leave these factors out of consideration and confine our attention to the question of brightnesses, and in particular to the brightness of the lamp fittings.

What the problem is, and previous attempts to solve it

The question to be put, therefore, is: what is the maximum permissible brightness of the lamp fittings for a person inside the room not to get a feeling of discomfort from the lighting system? To give an answer to this question that will satisfy practical needs it has to be dealt with in two stages. First a measure has to be determined for the border between "comfortable" and "uncomfortable" lighting. Secondly we must try to find some law

[1]) See, e.g., A. A. Kruithof and A. M. Kruithof, Basic principles for the formulation of illumination standards, Philips Techn. Rev. **10**, 214-220 1949, (No. 7).

[2]) W. Harrison, What is wrong with our fifty-footcandle installations? Ill. Eng. **31**, 208, 1937.

according to which it can be predicted whether certain conditions of illumination create a situation on this or that side of the limit. Such a law must of course be based upon the results of experiments (in these experiments the choice of the criterion is involved).

Among the investigations so far carried out in this direction we mention those undertaken by Luckiesh and Guth [3]) and by Harrison [4]). The first-mentioned investigators followed up the 20-years older measurements of Holladay [5]), which concerned glare and were obtained by what is known as the shock method. Holladay let a glaring source of light appear for a moment in the visual field of an observer. When the brightness of the light source is very high the observer's visual capacity is temporarily reduced, and this reduction can be measured. When the brightness of the light source is moderate there is no question of such a reduction of the visual capacity but the observer gets a feeling of discomfort. The degree of this "discomfort glare" was determined by Holladay, and later by Luckiesh and Guth, by asking the observer to judge — immediately after the appearance and subsequent disappearance of the glaring light — in what degree, from scarcely noticeable to quite intolerable, he would place the feeling of discomfort. In this way the discomfort glare was determined as a function of a series of variables: the brightness B_a and the dimensions of the light source, the brightness B_s of the surroundings, the angle α between the direction of vision and the direction from the eye to the light source, and the horizontal distance d away from the lamp.

Harrison worked out all this experimental material into a formula. To each source of light in a given lighting situation he ascribed a glare factor (f) as a measure for the discomfort glare caused by that light source. For this glare factor he gave the formula (somewhat simplified by us):

$$f = k \frac{B_a{}^2 \omega}{B_s{}^{0,6} \sin^2 \alpha}, \quad \dots \dots \quad (1)$$

where ω is the solid angle under which the observer sees the light source and k is a factor the further definition of which is of no signifiance here. When there are several light sources together in the field of vision — so Harrison assumed — the various facors f could be added up. The assumption that these factors f would be additive can be made plausible by the consideration that f can be interpreted as the surface of a source of light (with fixed brightness) necessary in a standard situation to cause the same degree of discomfort glare as that caused by the light source in question.

For the total glare factor Harrison gave as criterion that, for the lighting not to cause any feeling of discomfort, this must not exceed 15.

This manner of representation has its value as a first attempt to arrive at a quantitative treatment of the problem, but it has to be pointed out that in the experimental material underlying this manner of approach there are some assumptions which make its applicability to our problem seem doubtful.

In the first place let us consider the criterion. The situation in which the observer finds himself placed for experiments according to the shock method is entirely different from that which we have in mind when considering whether a lighting system is comfortable or not: it is a matter of the feeling of discomfort that may be experienced when staying for a long time in a lighted room.

In the second place, the experiments were carried out only with round or practically round sources of light. Considering the extent to which tubular fluorescent lamps are now being used, especially for high levels of illumination in large rooms and halls, obviously it is questionable whether the results reached by Holladay and by Luckiesh and Guth, with Harrison's conversion to equivalent surfaces (glare factors), can be taken for granted as being valid also for elongated sources of light.

These and other considerations have led the Illumination-Engineering Laboratory of Philips Works in Eindhoven to carry out a series of new experiments with as starting point the same question as put at the beginning of this section of our present paper [6]).

Set-up and manner of conducting the experiments

In our experiments we aimed at making the criterion approximate as closely as possible to actual practical conditions. From the ceiling of the room a lamp fitting was suspended whose brightness could be controlled by the observer himself. The lamps used for the general lighting

[3]) M. Luckiesh and S. K. Guth, Discomfort glare and angular distance of glare sources, Ill. Eng. **41**, 485, 1946.

[4]) W. Harrison, Glare ratings, Ill. Eng. **40**, 525, 1946; W. Harrison and P. Meaker, Further data on glare ratings, Ill. Eng. **42**, 153, 1947.

[5]) L. L. Holladay, The fundamentals of glare and visibility, J. Opt. Soc. Amer. **16**, 271, 1926.

[6]) These experiments have already been reported in a paper prepared by D. Vermeulen and J. B. de Boer for the conference of the International Commision on Illumination held in Paris in 1948; this report will shortly be published in Applied Scientific Research.

of the room were invisible to the observer and could be adjusted independently of the test light source. The observer was asked to imagine himself as being seated in an office and engaged in his normal work. Then, looking up in a horizontal direction,

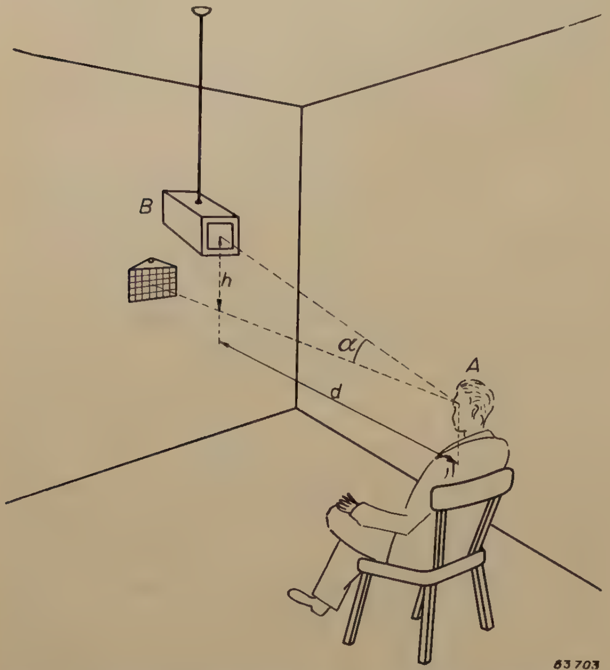

Fig. 1. Set-up for determining the permissible brightness of a square lamp fitting. The observer (A) himself adjusts the brightness of the light box (B) to what he judges to be just a tolerable value. The ambient brightness can be varied independently of the light box, as also the suspension height h of the box and the distance d from the observer. The luminous plane observed is always perpendicular to the viewing direction (thus it remains square). The tests were carried out with a number of light boxes of different sizes.

he had to adjust the brightness of the test fitting suspended in his field of vision until the limit of what he felt to be the tolerable brightness was reached.

Of course this limit is not sharply defined, the tolerability of a brightness observed in this way being judged from personal impression, so that great differences in the results are to be expected. Nevertheless it will presently be shown that with this, in itself vague, criterion a fairly well determined limit can indeed be found.

For the first series of tests we used as lamp fitting a square light box which can be taken as being the equivalent of a diffuser such as is commonly used for office lighting with incandescent lamps. Boxes of different sizes were suspended at various heights from the ceiling, so that the solid angle ω and the viewing angle α under which the fitting was observed could be varied independently of the likewise variable horizontal distance d from the observer to the fitting (*fig. 1*). Together with the ambient brightness already mentioned there were thus four independent variables as a function of which the brightness adjustments of each observer had to be determined. In this way data were obtained with which, taking our new criterion as basis, a law could be formulated analogous to that of formula (1).

In a second series of experiments the square light box of fig. 1 was replaced by an oblong one, by way of imitation of a fitting in which tubular fluorescent lamps could be used. Since the question in this case was mainly to decide whether a representation like that given by Harrison (conversion to equivalent surfaces) would hold for light sources of any shape, this series of tests was on a less extensive scale, only one light box being used, of certain dimensions (1.40 m long, 0.10 m high, placed horizontally, with the luminous surface always perpendicular to the line of sight).

Finally another series of tests were carried out with a somewhat different object, particularly concerning the construction of the well-known fittings with so-called louvres for fluorescent lamps. Practice has shown beyond doubt that the relatively low brightness of the fluorescent lamp (about 0.4 stilb) is still not low enough for these lamps to be mounted without any screening in the field of vision; the farther the lamps are removed from the central part of the field of vision (the larger the viewing angle α), however, the less trouble is experienced from the direct radiation of the lamps.

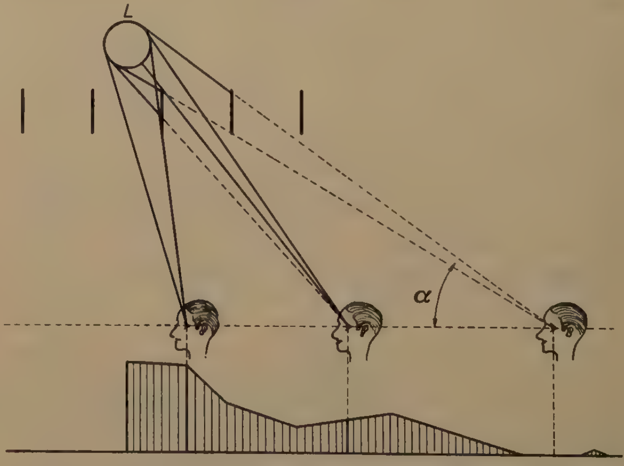

Fig. 2. Schematic representation of a lamp fitting with louvres for fluorescent lamps. Owing to the partitions the observer sees less of the lamp the farther he stands away from it and, thus, the smaller the viewing angle α. The ordinates of the hatched plane indicate the visible surface of the lamp at each distance.

A similar diagram can be drawn for the case where the lamp lies in the plane of the drawing and not, as here, perpendicular to that plane. Since "TL" lamps, thus viewed in the longitudinal direction appear to have a lower brightness than when viewed transversely, the partitions are allowed to be more widely spaced in this direction.

By placing vertical screens under the lamp(s) the surface visible to an observer is reduced, the more so the farther the observer is away from it, and thus the smaller the angle α with respect to the observer when he is looking in a horizontal direction (*fig. 2*). In this situation, therefore, it is not asked what is the permissible brightness with a given surface, but inversely what is the permissible surface with a given brightness. Our set-up was accordingly adapted by confronting the observer with a horizontally suspended, naked, fluorescent lamp, the visible surface of which he was able to vary with the aid of a horizontal slit of variable width (*fig. 3*). He was then asked

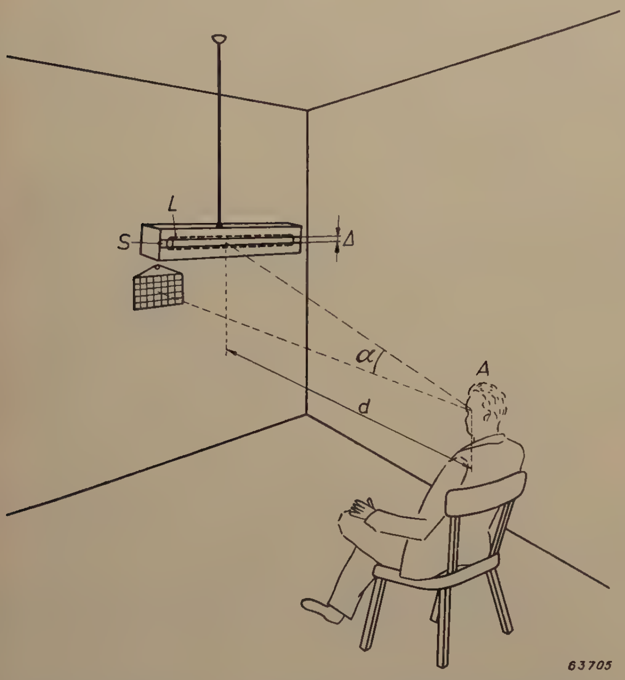

Fig. 3. The width Δ of the slit S through which the naked fluorescent lamp L is seen can be adjusted by the observer (A) himself to the value he judges to be just tolerable.

to adjust the width of the slit Δ (height of the visible lamp surface), while looking in the horizontal direction, so that the presence of the lamp did not cause him to feel any discomfort. These experiments were carried out with lamp lengths of 0.60, 1.20 and 2.40 m, to imitate the case where a number of fluorescent lamps are mounted in a line.

It has already been pointed out that the adjustments obtained in one and the same situation must inevitably show a great spread. An obvious method to cope with these difficulties is to define the required permissible brightness (or width of slit) as that brightness which 50% of the observers regard as being just tolerable. When plotting for each brightness value the percentage of observers whose adjustments exceeded that value a step-like graph is obtained as in *fig. 4*. The influence of the spread, as given expression in the step-like graph, is for the greater part eliminated when that line is replaced by a continuous curve and the required

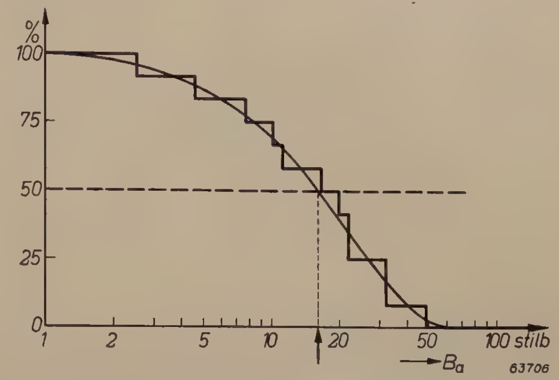

Fig. 4. For any lighting situation (ambient brightness B_s, solid angle ω under which the fitting is seen, viewing angle α) the adjustments for the permissible brightness B_a of the fitting as made by the various observers are arranged to form a step-like graph: the ordinate for each value of the brightness B_a indicates the percentage of observers judging that brightness to be permissible. The continuous curve smooths out the deviations among the observations seen in the step-like graph, the point of intersection with the 50% line giving the required "permissible brightness" for the lighting situation in question.

permissible brightness is read from the point where that curve intersects the 50% line. The more steps there are, that is to say, the larger the number of observers employed, the easier it is to draw the continuous curve. In our experiments all adjustments were made by 12 and in some cases even by 15 observers, a very much larger number than were employed for the investigations previously referred to. Of course, for each observer, in each measuring situation, again the average was taken of a number of adjustments made, starting from the side of low as well as high brightnesses.

Results of the tests

In view of the large number of parameters only an extract of the results can be given here.

Fig. 5 relates to the first series of experiments with a square source of light. Here the permissible brightness has been plotted as a function of the solid angle ω under which the lamp is seen, for three different values of the viewing angle α; the ambient brightness was 2×10^{-3} stilb (cd/cm^2), corresponding to the brightness of white paper under an illumination of 100 lux. The general trend of the lines answers the expectation: with increasing apparent size (ω) of the source of light the discomfort glare apparently becomes stronger and the permissible brightness accordingly less. This is in agreement, too, with the simple principle of the addition of glare

factors according to Harrison, since a large source of light may be regarded as being composed of two or more adjoining small sources of light.

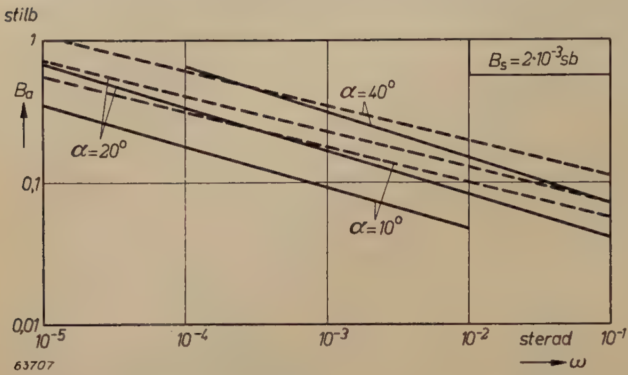

Fig. 5. Permissible brightness B_a of a square lamp fitting as function of the solid angle ω for three different viewing angles α. The corresponding lines according to Luckiesh and Guth [3]) are indicated in broken lines. Ambient brightness $B_s = 2 \times 10^{-3}$ stilb.

Also as regards the order of the values found there is reasonable agreement with former measurements, as appears from the dotted lines representing the results obtained by Luckiesh and Guth. This, however, is no longer true when we come to compare the results for small ambient brightnesses; see *fig. 6*, which applies for 0.04×10^{-3} stilb. According to our results, especially for large solid angles, the permissible brightnesses in this case are very much smaller than those according to Luckiesh and Guth, the difference being attributable mainly to the different criteria used. It seems to us, however, that all the same, judging from our measurements, the discomfort glare of the square (or round) light source, both with high and with low ambient brightnesses, can be described by a formula similar to (1), be it with slightly different powers (see the report quoted in footnote [6]).

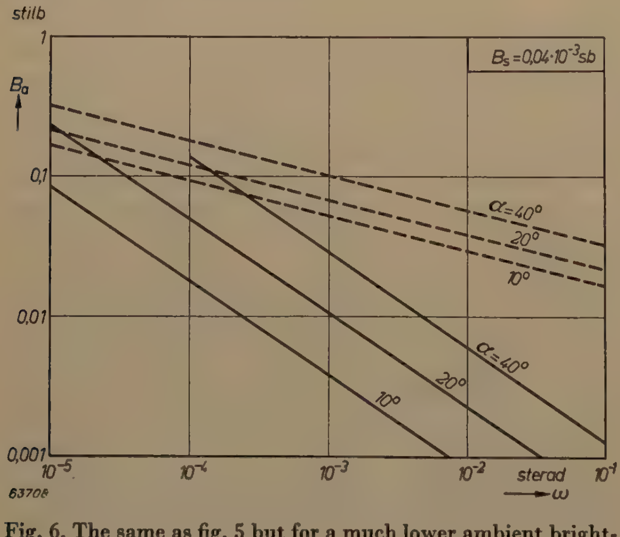

Fig. 6. The same as fig. 5 but for a much lower ambient brightness $B_s = 0.04 \times 10^{-3}$ stilb.

The results of the second series of tests, with elongated light source, showed more serious discrepancies. *Fig. 7* gives the permissible brightness again as a function of the solid angle ω and with the viewing angle α as parameter, with an ambient brightness of 2×10^{-3} stilb; the curves for a square source of light given in fig. 5 are reproduced here in fig. 7 in broken lines. The first thing to be noticed is that with an elongated source of light a very much higher brightness is permissible than in the case of a square or round one with the same visible surface! Thus we find confirmation of our surmise that it is not to be assumed that only the surface and not the shape governs the discomfort glare from a lamp. On the contrary, the shape appears to have a decided influence [7]). Physiologically the influence is to be so interpreted that the light striking the eye from the side makes it less sensitive to the glaring effect of the light in the central part of the field of vision.

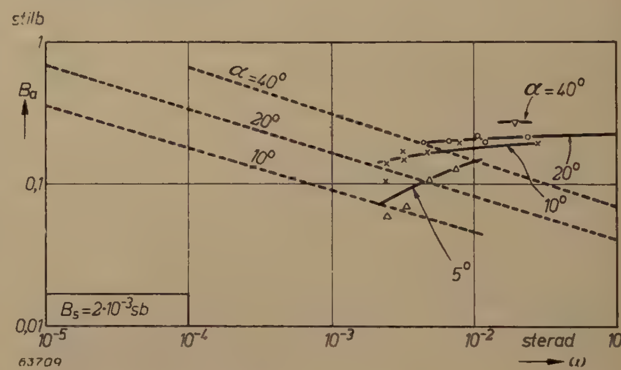

Fig. 7. Permissible brightness B_a of an elongated, horizontally suspended lamp fitting (visible surface 1.40 m $\times$ 0.10 m) as a function of the solid angle ω for different viewing angles α. The dotted lines are the corresponding lines from fig. 5 for a square fitting. Ambient brightness $B_s = 2 \times 10^{-3}$ stilb.

This effect appears to be so strong that in fact in fig. 7 (where the increased value of ω was obtained by bringing the observer nearer, thus with the light striking his eye more and more from the side) the permissible brightness increases with increasing solid angle ω. This entirely unexpected result goes to show that the simple method of adding up the glare factors of separate sources of light can certainly not be applied for lamp fittings that are not round in shape.

Finally we come to the series of experiments with naked fluorescent lamps and variable slit width.

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[7]) From recent investigations conducted by P. Petherbridge and R. G. Hopkinson (Discomfort glare and the lighting of buildings, Trans. Ill. Eng. Soc. 15, 39-71, 1950, No. 2), where the shock method was likewise departed from in favour of a criterion somewhat analogous to ours, the shape of the light source proved to have a similar effect on glare.

Some of the results are represented in *fig. 8*, which has been constructed somewhat differently from the others: here the permissible slit width Δ has been plotted as a function of the distance d from the

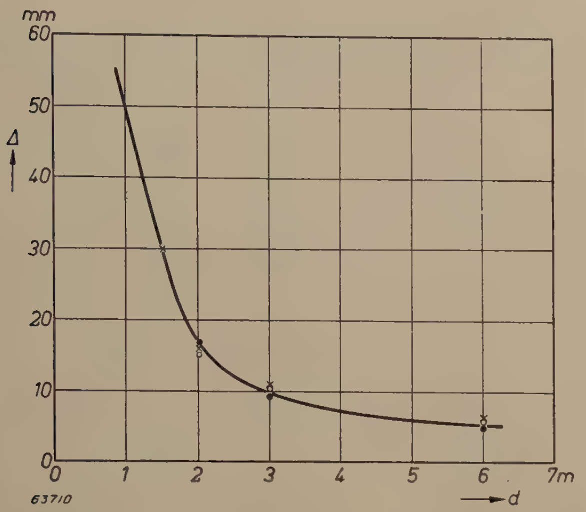

Fig. 8. Permissible visible width Δ of a fluorescent lamp in the set-up according to fig. 3, as a function of the distance d from the observer. The lamp is suspended 1.50 m above the eye level of the observer. Ambient brightness 3×10^{-3} stilb. The small circles refer to a lamp length of 0.60 m, the small crosses to one of 1.20 m and the dots to a length of 2.40 m.

observer (cf. fig. 3), for a brightness of 0.4 stilb of the lamp ("TL" 40 watt) and an ambient brightness of 3×10^{-3} stilb; the lamp was suspended at a level 1.50 m higher than that of the observer's eye (from this datum the viewing angle α can be derived for any distance d). The general trend of the curve found again agrees with the expectation: the smaller the viewing angle α the more the observer has need of screening the light source (even if the reduction of α is accompanied by a reduction of ω). What strikes one as peculiar, however, is that practically the same curve is found for the three different lamp lengths of 0.60, 1.20 and 2.40 m (see the different measuring points). Thus we have here again a striking contradiction of the "glare factor" method, according to which with twice the length half the permissible width would have been expected.

Conclusion

It would be disappointing if from our experiments nothing else could be concluded than that a line of reasoning hitherto followed and in itself attractive may lead to erroneous predictions. The results reached have, however, indeed something positive about them. In the first place, even limited in scope as they were, these experiments can already serve for certain quantitave conclusions to be drawn as regards the most efficient construction of lamp fittings. It can be deduced, for instance, that the brightness of 0.3 stilb generally accepted as permissible for diffusers is really a factor 2-3 too high. When there are many diffusers, some of

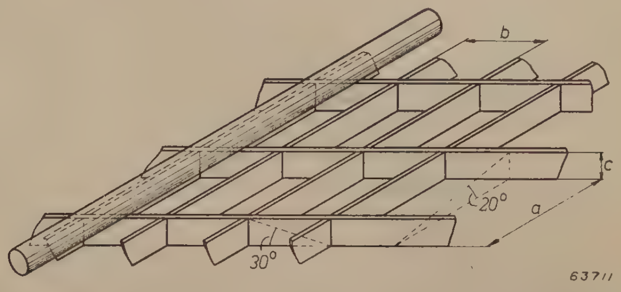

Fig. 9. Schematic diagram of a louvre. The "TL" lamps are mounted above the louvres in the direction shown (only one lamp has been drawn). The ratios of the dimensions a, b, c of the cells ensure complete screening of the naked lamps for viewing angles of respectively $\alpha < 30°$ and $\alpha < 20°$ (cf. fig. 2). Within reasonable limits one is free in the choice of the absolute dimensions. Also the pattern of the louvres can be altered on aesthetical or practical grounds provided the same screening angles are maintained.

which at least the eye cannot escape, the lighting is certainly not comfortable. Further it may be deduced how the louvres have to be constructed in order that under any situations occurring (eye level and distance from the observer) the fluorescent lamps may not cause any feeling of discomfort. It is in accordance with these results that, among others, the louvres sketched in *fig. 9* have been designed, which are employed, for instance, in the fitting illustrated in *fig. 10*.

Fig. 10. Top: Fitting for four "TL" lamps of 40 W provided with rhombic louvres with screening angles according to fig. 9. This type of fitting was employed on a large scale for the lighting of the new head offices of the Rotterdam Bank at Rotterdam.
Bottom: The same lamp fitting opened.

In the second place it is to be regarded as a positive result of our experiments that they do at least indicate the direction in which the reality deviates from the "glare factor" hypothesis. In fact, the conclusions that are to be drawn both from fig. 7 and from fig. 8 prove that the total discomfort glare from several light sources is less serious than would appear from an adding up of their separate glare effects. It has even been shown that in some cases the discomfort glare is reduced by the addition of further bright surfaces! The following actual fact taken from experience may be added to this statement. When an elongated source of light at right angles to the direction of vision and observed under a small viewing angle α has a brightness that is not disturbing, it appears that a number of identical sources of light with gradually increasing angle α can be placed in the field of vision simultaneously without causing the lighting to become uncomfortable. This is of great importance in practice, since it means that when illuminating a long hall with translucent "TL" fittings it is only necessary to make sure that the fittings farthest away from the observer do not cause any feeling of discomfort.

To obtain a full insight into the question of discomfort glare from several sources of light simultaneously present in the field of vision, more extensive experiments will, however, be needed with different configurations of the light sources.

Summary. The lighting installation in an office or suchlike space may be deficient not only on account of the level of illumination being too low but also by reason of an unsatisfactory distribution of brightness in the field of vision, as a consequence of which a feeling of discomfort may be caused, especially when one has to stay in the room for any length of time. From investigations into the suitable distributions of brightness ("brightness engineering") it appears, inter alia, that the fittings suspended in the room should not have too high a brightness. Previous investigations carried out in regard to the permissible brightness of fittings were based on Holladays's shock method, whereby the source of light was only momentarily shown to the observer and then his judgment of the glare, or of "discomfort" glare, was determined. In a series of experiments carried out by Philips this method has been departed from: the observers (there were at least 12, so as to get reliable results in spite of the rather great spread) were required so to adjust the brightness of a test lamp fitting themselves, under various conditions, that no feeling of discomfort would be felt when staying in the room a long time. The tests were performed with a square and an elongated source of light (the latter in imitation of a fitting with fluorescent lamps), whilst in a further series of experiments it was possible to investigate the dimensions required for the partitions in a fitting with louvres. Inter alia, these tests yielded the surprising result that the elongated light source may be allowed to have a greater brightness the greater the solid angle under which it is seen, such in contrast to the square source of light. From this it appears that Harrison's method, according to which the total glare effect of a number of sources of light is derived from the addition of their separate "glare factors" (equivalent surfaces), cannot hold for general application because it does not allow for the shape of the light sources. The results of these experiments permit of some conclusions being drawn that are of practical value.

RADIOGRAPHIC EXAMINATION OF ELECTRONIC VALVES

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The demands made nowadays upon electronic valves for certain applications have led to the dimensions of the electrodes and their clearances being made smaller and smaller. Naturally the tolerances are then also very narrow and thus machining has to be most precise. For instance, in the case of a certain high-frequency pentode with coaxial cylindrical electrodes, an average eccentricity of 20 μ of the control grid with respect to the cathode is sufficient to change the valve characteristic to such an extent that the valve no longer meets the specification.

Formerly the cause of such a deviation from the prescribed characteristic was traced by removing the bulb of the valve and carefully detaching the anode and the surrounding screen with cutters and pliers, then inspecting and measuring the cathode and grid system. The latter was done with what is called a measuring projector, an optical apparatus with which a strongly magnified (up to 100 times) undistorted and bright silhouette of the object under examination is projected onto a frosted glass plate, the necessary measurements then being taken on this silhouette with a ruler.

This method of dismantling of the valve is not entirely satisfactory, as not only does it destroy the sample but there is always the risk of distortion of those parts which have to be measured. Nevertheless, under good circumstances, an accuracy of measurement of about 10 μ can be attained.

Recently a method has been developed which, while it gives the same accuracy of measurement as does the older method, avoids all possibility of distortion of the valve electrodes. By this new method it is possible to use X-rays as a means of projection.

To obtain good definition an X-ray tube with the smallest possible focus has to be used. When the object to be examined is placed at B (see *fig. 1*) at a distance v from the focus A, the dimension of which is Δ, then in a plane C at a distance b behind the object a shadow picture is formed with a geometrical blurring

$$\frac{b}{v}\Delta .$$

Details in the picture that are smaller than this blurring cannot be observed.

Since the projected shadow is $(b + v)/v$ times the size of the object, the smallest perceptible details of the object are given by:

$$\frac{v}{b+v}\Delta\frac{b}{v}=\frac{b}{b+v}\Delta .$$

In the set-up employed $v = 200$ cm,
$b = 4$ cm,
$\Delta = 0.3$ mm,

so that the resolving power amounts to 6 μ. The projected shadow is then only 2% larger than the object.

There are two ways of viewing the image: with the aid of a fluorescent screen or by means of a photographic recording. The sharpness of a fluorescent screen is quite inadequate, so that we are obliged to use the photographic method, although it takes more time.

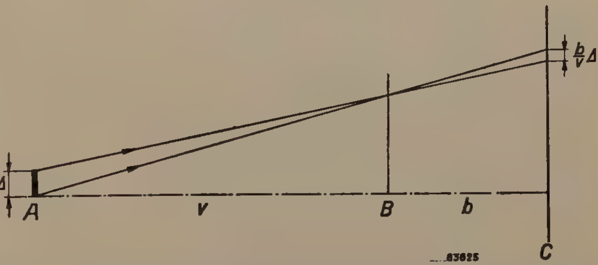


Fig. 1. Blurring of the X-ray image. A focus of the X-ray tube, B object plane, C image plane. With the set-up described here the object distance v = 200 cm, the picture distance b = 4 cm.

The normal photographic plate or film, emulsified on one side, with a grain of only a few microns, gives good results. An intensifying screen cannot be used because this would reduce the sharpness too much. A special fine-grained material can be used and gives a greater accuracy of measurement, but since it takes a rather long time to develop (15 to 20 min) a normal plate is mostly used so as to save time, the developing time then being only 5 minutes.

With the set-up now in use a "Rotalix" tube of the type O 75 is employed, this being a tube with two foci, but for our purposes only the smaller focus is used (apparent focus dimensions 0.3 × 0.3 mm [1])).

[1]) For a description of this tube see G. C. E. Burger, B. Combée, and J. H. van der Tuuk, X-ray fluoroscopy with enlarged image, Philips Techn. Review 8, 321-329, 1946.

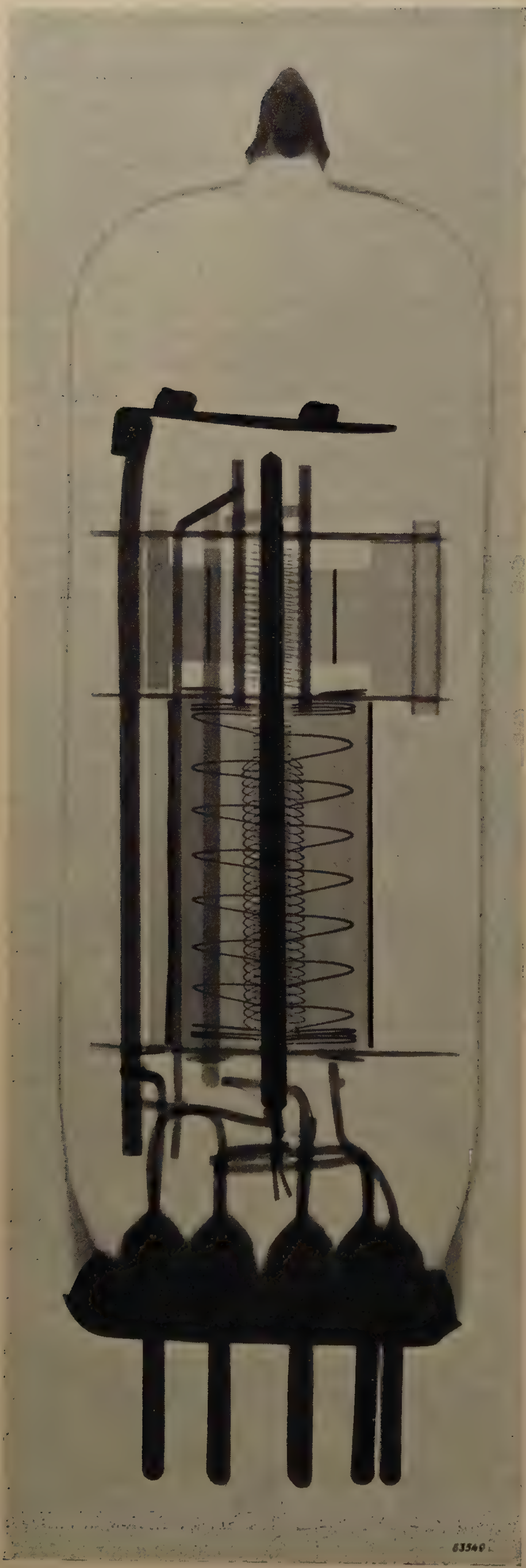
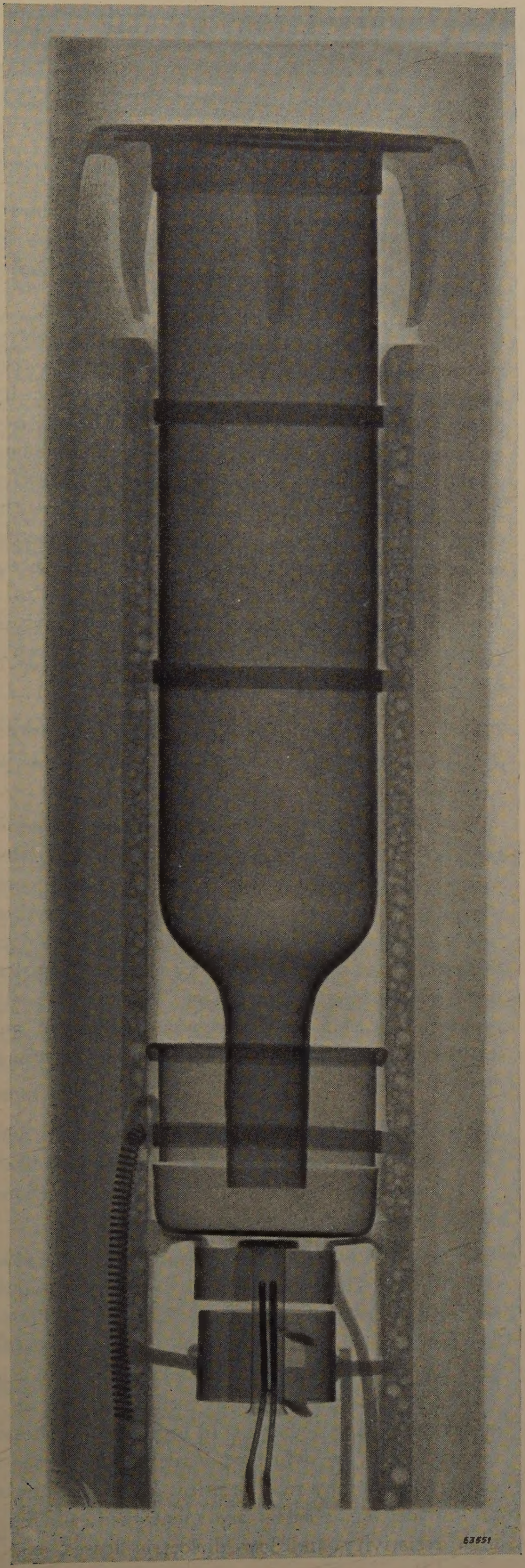


Fig. 2 Combined pentode and triode for television reception, type ECL 80.
Right: Natural-size photograph. *Left:* X-ray photograph enlarged 4 times. The three grids of the pentode are clearly seen in the lower part of the valve. The cylindrical anode is distinguished by the darker field behind the grids and the two lines running down the side of them. The indirectly-heated cathode is concealed by the supporting wires of the grid, but the coiled filament can be seen at the bottom of the valve. The second grid, which does not reach right to the top, has apparently been distorted at the top end when the winding jig was removed and this was the cause of the characteristic deviating beyond the tolerance and the valve being rejected on the testing bench.

The X-ray tube, the object and the film are screened off with an iron case lined with lead. On the front is a fluorescent screen on which a silhouette of the valve being examined can be seen, so as to be able to set it in the right position. The valve is positioned by means of three knobs outside the case, with which the valve can be turned in two directions at right angles to the X-ray beam and also moved vertically. The mechanical transmission consists of three flexible spindles. The operating panel for the X-ray tube is situated underneath the fluorescent screen and is fitted with a time switch.

For studying the behaviour of the valves while heating up provision has been made for connecting them to the working voltages.

The exposure time varies from 1 to 2.5 minutes according to whether the valves being examined have lime-glass or lead-glass bulbs. Since it is not usually necessary to keep the photograph, the fixing and rinsing is done quickly and the photograph then rapidly dried with heated dry air. In this way it is possible to finish taking the measurements 30 minutes after starting operations, a factor of



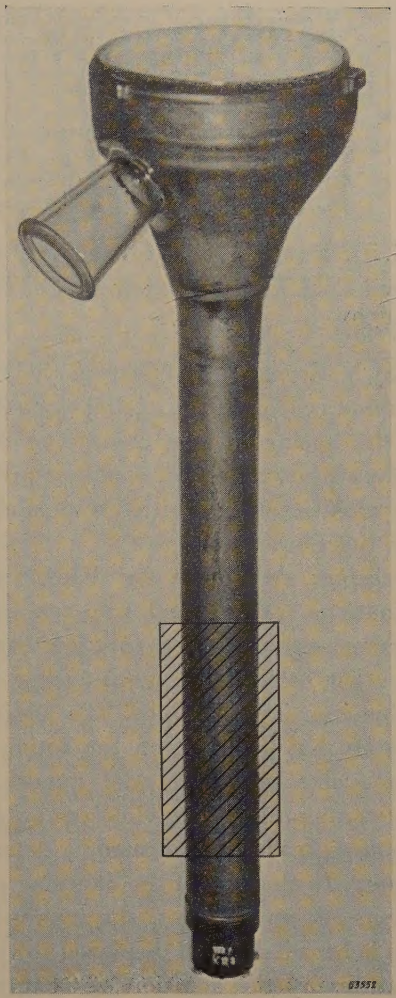


Fig. 3. Cathode-ray tube for television projection, type MW 6-2. Right: photograph of the tube (half the actual size). Left: X-ray photograph of the electron gun (hatched part in the photograph on the right) enlarged 3.5 times.

great importance when it is necessary to intervene quickly in the production process.

The photographs are measured up under an optical projector in the same way as was formerly done with the dismantled systems of the valves.

The accuracy of the measurements can very easily be checked by photographing a gauge together with the objects. Practice has proved that a total accuracy of 10 μ is reached.

The photographs reproduced here give an idea of the sharpness obtained, though naturally much of it is lost in the reproduction.

H. B. van Wijlen

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF THE N.V. PHILIPS' GLOEILAMPENFABRIEKEN

Reprints of these papers not marked with an asterisk can be obtained free of charge upon application to the Administration of the Research Laboratory, Kastanjelaan, Eindhoven, Nederlands.

1921: J. D. Fast: Ageing of iron and steel (Iron and Coal Trades Review **160**, 837-844, April 1950).

A study has been made of parts played by oxygen, nitrogen and carbon in the ageing of unalloyed iron and in the ageing of iron containing manganese. For this purpose, pure iron was first prepared and known quantities of impurities were added, separately or together.

Quench-ageing: As shown by Vickers hardness determinations, carbon and nitrogen cause significant quench-ageing in iron that is otherwise pure. On the other hand, the quench-ageing of oxygen-containing iron is very slight. The addition of 0.5 per cent Mn has no effect on the action of carbon but practically suppresses the quench-ageing of nitrogen-containing iron. This remarkable effect of manganese has been confirmed by determinations of damping. In the case of the damping of torsional oscillations set up in wires, the maximum due to nitrogen is broadened and displaced towards higher temperatures by the addition of 0.5 per cent Mn. The experiments indicate that the nitrogen atoms are situated preferentially in the interstitial positions which are in the immediate neighbourhood of the manganese atoms. The observed damping shows that the nitrogen atoms can make jumps around the atoms of manganese, but that they find it difficult to leave these atoms. Heating for some tens of hours at 200 °C is necessary to precipitate a noticeable quantity of nitrogen in the alloys containing manganese.

Strain-ageing: Oxygen does not cause strain-ageing in iron. The essential cause of this phenomen is nitrogen, less than 0.001 per cent of which suffices to produce the maximum strain-ageing. Even at room temperature this ageing takes place with great speed. Strain-ageing due to carbon only appears at a noticeable speed at elevated temperatures, such as 100 °C. This difference between the effects of carbon and nitrogen apparently depends principally on the difference in their solubilities in iron. The time required for strain-ageing is controlled mainly by the product of the diffusion coefficient and the solubility of carbon or nitrogen in iron. Manganese has no appreciable effect on the strain-ageing caused by carbon or nitrogen.

1922: N. W. H. Addink: A rapid and accurate method of measuring line intensities in spectrochemical analysis (Spectrochimica Acta 4, 36-42, 1950, No. 1).

A method of measuring line intensities in spectrochemical analysis is developed, based on the principle of visual comparison with standard density lines (standard paper density scale). The method gives results as accurate as those obtained by means of the densitometer (5%): it includes a correction for background intensity and it speeds up the quantitative analysis, as the qualitative inspection of the spectrum and the measurement of line intensities can be made simultaneously. The use of a densitometer is eliminated. Examples of analysis results and of the time necessary for quantitative analysis according to this method are given.

1923: C. J. Dippel: The metal-diazonium process (Photographic Journal **90 B**, 34-41, 1950, No. 2).

A general survey is given of the principal characteristics of the new metal-diazonium reproduction process: the transformation of a latent image composed of an organic light decomposition product into a latent image composed of mercury droplets, followed by an intensification by means of physical development into a silver image. The characteristic properties of this new process are described and its high resolving power of 1,200 lines per mm is stressed.

1924: J. M. Stevels: Quelques nouveautés dans les recherches sur le verre (Verres et Réfractaires 4, 3-9, Febr. 1950, No. 1). (Some novelties in glass research.)

Description of sintered glass and its applications (see Philips Techn. Review **8**, 2-7, 1946) and of scale-glass (Philips Res. Rep. **1**, 129-134, 1946). The latter consists of small scales having a surface area af obout 1 mm² and a thickness of 1 to 5 μ, which are superimposed by sedimentation in a suitable liquid and which hold together by cohesion forces. It can be deformed while wet, whereas in a dry state it may replace mica. Finally a number of low-melting glasses are mentioned, having a high resistivity and low dielectric losses, e.g. a

glass consisting of 45 SiO_2, 32 PbO, 5 CaF_2, 4 Na_2O and 14 K_2O (percent by weight), which can be sealed to iron. Some properties (resistivity and loss angle) as a function of temperature and frequency are shown in the form of graphs.

1925: G. Diemer and J. L. H. Jonker: Secondary-emission valve as wide-band amplifier for decimeter waves (Wireless Eng. **27**, 137-143, May 1950).

An experimental secondary-emission valve is described. The high figure of merit (g_m/C = 3.0 mA/V-pF) that is obtained by adding one stage of secondary emission to a grounded-grid triode of rather conventional construction makes the valve useful as a wide-band amplifier for those cases where there is no need for a very low noise figure; typical figures are: at 1m wavelength 30 db gain (G) with a bandwidth (B) of 3.5 Mc/s, at 50 cm G = 15 db with B = 20 Mc/s, at 30 cm G = 10 db with B = 10 Mc/s. The maximum power output is for $\lambda > 1$ m about 1.5 watts. At 7 m wavelength the noise figure amounts to 12 db; this rather high value is due to the secondary emission. It is shown that for this secondary-emission noise a kind of space-charge smoothing effect exists.

1926: E. W. Gorter: Saturation magnetization of ferrites with spinel structure (Nature, London **165**, 798-800, May 20, 1950).

The magnetic moment per molecule M_s of components $x\ ZnFe_2O_4 + (1 - x)\ Me^{II}Fe_2O_4$, where Me^{II} is a divalent metal, are measured at liquid-oxygen and liquid-nitrogen temperatures and plotted as a function of x. The curves show a maximum in the neighbourhood of $x = 0.4$, the tangents at $x = 0$ converge to the value $M_s = 10$ Bohr magnetons at $x = 1$. The results are in agreement with Néel's theory.

1927: H. G. Beljers and D. Polder: g-factors in ferrite materials (Nature, London **165**, 800, May 20, 1950).

The g-factors of a number of ferrites (see No. **1926** of these abstracts) have been determined by studying the absorption of microwaves in small spherical samples of the material (see No. **1850** of these abstracts).

1928: J. L. Snoek: Grain-boundary slip and magnetic relaxation at high temperatures in iron (Physica, The Hague **16**, 336, 1950, No. 3).

Measurements of Fahlenbrach on magnetic relaxation at high temperatures (400 °C to 600° C) in iron and silicon iron are compared with measurements of the internal damping (400 °C to 600 °C) of fine-grained samples of iron (grain size 3μ) by Kê. Both phenomena are ascribed to grain-boundary slip. This gives additional support to the author's theory of the room-temperature after-effect, which makes elastic after-effect in the Bloch boundary zone solely responsible for the observed time lags.

1929: J. L. Snoek: The weak ferromagnetism believed to be present in α-Fe_2O_3 and other antiferromagnetic compounds (Physica, The Hague **16**, 333-335, 1950, No. 3).

The evidence for a small permanent moment observed below the critical temperature in most antiferromagnetic compounds is traced back to lattice imperfections.

1930: F. A. Kröger and J. Dikhoff: Trivalent cations in fluorescent zinc sulphide (Physica, The Hague **16**, 297-317, 1950, No. 3).

Incorporation of monovalent cations in a lattice consisting of divalent ions is only possible to an appreciable extent when the lack of positive charge resulting from the substitution of a monovalent cation for a divalent one is compensated. This compensation can be achieved by a simultaneous incorporation of monovalent anions, or of cations of a valency higher than two. On this basis it is explained that ZnS becomes fluorescent by the monovalent activators Ag^+, Cu^+, Au^+ and Zn^+ when halogens or trivalent cations are present. Some of the trivalent ions incorporated in this way are found to cause effects of their own (electron traps, fluorescence, killing of fluorescence due to the other centres). An atomic model of the centres of fluorescence is given.

1931: F. A. Kröger and N. W. Smit: The physical chemistry of the formation of fluorescence centres in ZnS-Cu (Physica, The Hague **16**, 317-328, 1950, No. 3).

On the basis of a model for the centres of fluorescence in ZnS-Cu arrived at in previous publications (Nos. **1902** and **1930**), the formation of centres with products prepared in controlled atmospheres of H_2S-HCl is discussed, assuming equilibrium to exist between the solid and the gas phase.

R 130: B. D. H. Tellegen and E. Klauss: The parameters of a passive four-pole that may violate the reciprocity relation (Philips Res. Rep. **5**, 81-86, 1950, No. 2).

Properties at a fixed frequency of linear, passive four-poles that may violate the reciprocity relation

are investigated. Necessary and sufficient conditions are derived for the four-pole parameters in order that the four-pole may be passive. For a four-pole containing only one resistor or one only reactor a certain connection exists between these parameters.

R 131: C. J. Bouwkamp: On the characteristic values of spheroidal wave functions (Philips Res. Rep. 5, 87-90, 1950, No. 2).

The first few terms of a power series expansion are given for the characteristic values of spheroidal wave functions of integral order and integral degree. Some numerical results are communicated for functions of order one.

R 132: W. F. Dil: Principles of measurements on coupled circuits (Philips Res. Rep. 5, 91-115, 1950, No. 2).

An analysis is given of an electrical circuit consisting of a valve and two coupled circuits, the coupling of which is capacitive as well as inductive and resistive. The behaviour of this circuit is characterized by the resonance curve and the gain at the central frequency. The conditions for symmetrical resonance curves are investigated. A survey is given of the most commonly employed methods for measuring the characteristic quantities such as coupling factors and qualities of the circuits.

Finally, new measuring methods are discussed which are practically free of the well-known difficulty of disturbing the normal operating conditions of the circuits, thereby affecting the accuracy of the measurement. Moreover, these methods offer the possiblity of measuring all the characteristic quantities of a system of coupled circuits having a symmetrical resonance curve.

R 133: R. Dorrestein: On the energy-flow distribution in certain types of paraxial beams (Philips Res. Rep. 5, 116-127, 1950, No. 2).

In a paraxial beam proceeding along the axis of a rotationally symmetric (light-optical or electrostatic) refractive medium, special pairs of cross sections may exist, in which the corresponding distributions of energy current density (or intensity) are mutually independent. They are called "independent" cross sections. From the intensity distributions in two such independent cross sections, one can calculate the intensity distributions in any other cross section by means of a suitable composition-product integral. The "Gaussian beam" is defined by a Gaussian intensity distribution and a Gaussian angular energy-flow distribution in one cross section. This class of beams possesses an infinite number of pairs of independent cross sections. The equation for the effective radius r, as a function of the distance z along the axis, is identical with the paraxial-ray equation for $r(z)$ in cylindrical coordinates z, r, φ.

R 134: R. Dorrestein: Note on the image formation in cathode-ray tubes (Philips Res. Rep. 5, 128-130, 1950, No. 2).

The theory of Gaussian beams (see No. **R 133** of these abstracts) is applied to the electron beam in a cathode-ray tube with a convential type of gun. It appears that in principle neither the paraxial crossover, nor the cathode image, but rather some intermediate point is to be imaged on the screen in order to yield the smallest possible spot. However, in practical cases this intermediate point nearly coincides with the crossover, which is in agreement with the generally accepted concept of image formation in cathode-ray tubes.

R 135: K. S. Knol and G. Diemer: Theory and experiments on electrical fluctuations and damping of double-cathode valves (Philips Res. Rep. 5, 131-152, 1950, No. 2).

A calculation is given of the internal resistance and the noise of symmetrical double-cathode valves containing two hot cathodes opposite each other. The results of measurements with indirectly heated oxide-coated cathodes agree with these calculations and show that, in contradiction to a theory of Fürth, the equivalent noise temperature of such valves does not exceed the true cathode temperature. Directly heated valves show small deviations from the theory, which are discussed.

R 136: G. Diemer and K. S. Knol: Low-level triode amplifier for microwaves (Philips Res. Rep. 5, 153-154, 1950, No. 2).

It is shown that — with a new type of cathode (the so called L-cathode, see Philips Techn. Review 11, 341-350, 1950, No. 12) — a low-noise triode for centimetre-wave amplification can be constructed, giving rise to an overall noise figure of 7 db.